IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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MEETINGS AND PAPERS

PHILADELPHIA SECTION

P. T. Vanderwaart, Chairman — L. O. Morrow, Secretary

Friday, May 8th, 1925

Joint meeting with the Lehigh Valley Engineers Club and the Lehigh Valley Section of the American Institute of Electrical Engineers.

Subject—"The application of Electricity to the Iron and Steel Industry"—John C. Reed, Elec. Engr., Bethlehem Steel Co., Steelton, Pa.

Behlehem Meeting, Hotel Bethlehem — Bethlehem, Pa.

CHICAGO SECTION

R. L. McIntosh, Chairman — W. H. Williams, Secretary

Wednesday, May 20th, 1925

"Primary Resistance Starters for Squirrel Cage Induction Motors"—By J. S. Rowan, President, Rowan Controller Co., Baltimore, Md.

Atlantic Hotel — Chicago, Ill.

CLEVELAND SECTION

R. E. Scovel, Chairman — A. R. Lintern, Secretary

May, 1925

"Electric Power Generation by Blast Furnace Plant," by O. C. Callow, Chief Electrician, Trumbull Cliffs Furnace Co., Warren, Ohio.

PITTSBURGH SECTION

R. E. Lewis, Chairman — John F. Kelly, Secretary

Saturday, April 18th, 1925

"The Automatic Blast Furnace," by Frank W. Cramer, Bethlehem Steel Company, Johnstown, Penna.

BIRMINGHAM SECTION

F. G. Cutler, Chairman — W. W. Garrett, Secretary

Executive Committee

W. H. Dunn — W. H. Gilbert

A. F. Elliott — W. B. Connally

EDITORIALS

FUEL SAVINGS CONFERENCE

The Combustion Engineering Division of the A. I. & S. E. E. announces their program for the Fuel Savings Conference, to be held in Pittsburgh, May 13 and 14, 1925.

The Technical Sessions will cover discussions pertaining to subjects which are of interest to the Steel Industry, whose problems have to do with less B.T.U.'s per ton.

One whole day will be devoted to COMBUSTION CONTROL. This subject will be discussed by Mr. Charles H. Smoot, of the Smoot Engineering Corporation; B. G. Bailey, of the Bailey Meter Company; Thomas Peebles, of the Hagan Corporation; G. S. Carrick, of the Carrick Engineering Company.

Another paper, which will arouse considerable interest among furnace operators, in the Iron and Steel Industry, will be INSULATION OF HOT SURFACES AND FURNACE WALLS, by L. B. McMillan, Consulting Engineer, Johns Manville Company.

Another paper, which will have to do with By-Products Fuels, will be presented by F. O. Schnure, of the Bethlehem Steel Company, Sparrows Point, Md.

The following Combustion Engineers of the Steel Industry will present discussions in connection with the above subjects: W. P. Chandler, Spec. Engr., Carnegie Steel Co., Pittsburgh, Pa.; Walter Flanagan, Steam Engr., Carnegie Steel Co., Youngstown, Ohio; H. C. Siebert, Comb. Engr., Bethlehem Steel Co., Bethlehem, Pa.; Strickland Kneass, Jr., Steam Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio; G. R. McDermott, Asst. Chf. Engr., Illinois Steel Co., South Chicago, Ill.; Mr. F. G. Cutler, Chief, Bureau of Steam Engr., Tennessee Coal, Iron and Railroad Co., Ensley, Ala. A. G. Witting, Asst. Chf. Engr., Illinois Steel Co., Gary, Ind.; F. W. Trexler, Comb. & Steam Engr., Bethlehem Steel Co., Johnstown, Pa.; W. J. Harper, Steam Engr., Donner Steel Co., Buffalo, N. Y.; C. H. Hunt, Chf. Engr., Weirton Steel Co., Weirton, W. Va.; J. C. Allen, Chf. Engr., Carnegie Steel Co., New Castle, Pa.; A. Steed, Supt. Power Division, American Rolling Mill Co., Middletown, Ohio.

A new feature in connection with the Fuel Savings Conference will be the Power Show. Fifty-two booths have been set aside for the use of the manufacturers who desire to bring their developments in fuel-consuming equipment to the attention of the Combustion Engineers of the Iron and Steel Industry.

AUTOMATIC BLAST FURNACES

Blast Furnace operators, who are seeking to eliminate the human factor in the production of Pig Iron, will be given an opportunity Saturday, April 18, at Pittsburgh, to learn how one of the progressive Steel Companies, the Bethlehem Steel Company, of Johnstown, Pa., has been able, with the use of Electricity, to practically eliminate the human element in stocking the furnace.

Twenty-four man-hours is all that is required to operate the complete charging equipment per day and night turn per furnace. It requires no stretch of the imagination to remember when it required 200 man-hours to perform this same service, and there are many plants today which are operating, which still requires 200 man-hours. Some of them even more.

This new innovation in Blast Furnace Practice was made possible through the efforts of Mr. C. S. Proudfoot, Electrical Engineer, of the Bethlehem Steel Company at Johnstown, Pa., whose researches and developments in this work extends over a period of 10 years.

A unique device used in connection with the operation of the Automatic Blast Furnace is the Automatic Stock Line Gauging Equipment, which allows a graphic record to indicate at all times the stock line.

Mr. F. W. Cramer, Assistant to the Electrical Engineer at the Bethlehem Steel Company, Johnstown, will present a paper before the Iron and Steel Engineers, Saturday, April 18, at the William Penn Hotel, Pittsburgh, Pa. The author will describe the installation and operation of the apparatus used in connection with the Automatic Furnace. A moving picture showing the blast furnace in operation will be one of the features of the meeting.

Blast Furnace operators from all over the United States will be in attendance at this emeting.

NOT MORE STEEL, BUT BETTER STEEL

For a long time executives, operators, engineers have spent their efforts and energies towards producing larger tonnages. Millions of dollars have been spent in the developments of Blast Furnaces, Open Hearth Furnaces, Rolling Mill Machinery, Power Stations, and any class of apparatus in which it was felt would help to increase the tonnages.

Very little has been said with regard to quality. Today, however, the Steel Makers in general have suddenly awakened to the fact that the customer's specifications are much more rigid and his demands much more exacting. How to meet this condition is now a problem of the Steel Maker and distributor.

If quality production is to be a factor in the Steel Markets of today, then more attention must be paid to steel processing. Rolling mill practices must be improved and closer attention must be given to material handling.

In the rehabilitation of existing plants, the executives, operators and engineers, who keep quality production in mind, as well as large tonnages, will be the ones who will be able to enjoy the benefits that are to be derived from foresight and preparedness.

Fuel Savings Conference

and

POWER SHOW

AUSPICES

Combustion Engineering Division

A. I. & S. E. E.

May 13 and 14, 1925 Wm. Penn Hotel, Pittsburgh

Forty spaces (3 ft. x 6 ft.) are available for the display of fuel consuming apparatus.

Prices are as follows:

Literature and drawings only	$ 25.00 per space
Working models	50.00 per space
Complete manufactured product ready for installation	100.00 per space

For Particulars As to Space, Details, etc. Apply to

Combustion Engineering Division, 706 Empire Bldg., Pittsburgh, Pa., or

W. P. Chandler, Special Engr., Carnegie Steel Co., Pittsburgh.
Walter Flanagan, Combustion Engr., Ohio Works, Carnegie Steel Co., Youngstown, Ohio.
H. C. Seibert, Combusion Engr., Bethlehem Steel Company, South Bathlehem, Pa.
S. Kneass, Jr., Combusion Engr., Youngstown Sheet & Tube Company, Youngstown, Ohio.
G. R. McDermott, Asst. Chief Engr., Illinois Steel Company, South Chicago, Ill.
F. G. Cutler, Chief, Bureau of Steam Engr., Tennessee Coal, Iron and Railroad Company, Ensley, Ala.
A. G. Witting, Asst. Chief Engr., Illinois Steel Company, Gary, Ind.
E. W. Trexler, Steam and Combustion Engr., Bethlehem Steel Company, Johnstown, Pa.
W. J. Harper, Steam Engr., Donner Steel Company, Buffalo, N. Y.
C. H. Hunt, Chief Engr., Weirton Steel Company, Weirton, W. Va.
J. C. Allen, Chief Engr., Carnegie Steel Company, New Castle, Pa.
A. Steed, Combusion Engr., American Rolling Mills Co., Middletown, Ohio.
John F. Kelly, Business Mgr., A. I. & S. E. E., Empire Bldg., Pittsburgh, Pa.

Wm. Penn Hotel, Pittsburgh ***May 13th and 14th***

Remodeled and Electrified Rod Mill

By S. N. ROBERTS*

TO INCREASE production and lower cost of producing good material is the aim of all mills. This has been attempted in various ways, each plant having its own particular problem to solve. What was done at one plant and some of the results will be given in this article. Every steel man knows certain defects in equipment under his charge that he would like to have remedied. In this case, there were troubles with both the rolling mill and drive, and both were remodeled to get the desired results. The changes were made in December, 1922, and the mill has been operating continually since that time.

The original installation was a combination Rod and Bar rolling mill, rolling from No. 5 rod to 1⅜" rounds and squares on 12 stands of 2 high rolls. Figure 1 gives the original layout. All stands were driven from a 1500 H. P. Corliss engine. Six stands of continuous roughing (2-12 inch, and 4-10 inch stands) were geared to engine shaft, while 3 shafts each driving two stands (2-10 inch and 4-8 inch) were driven by one 48" belt from engine flywheel. Billets were from 1½" to 2¼"—30 feet long. Rods were rolled in 12 passes except No. 5 rod, which took 14 passes. The two extra passes being obtained by double looping through No. 7 and No. 8 stands. Two bars were in roughing at same time. For merchant bar, various numbers of stands were used. Sizes up to ¾" being finished in No. 12 stand and larger in No. 8 stand.

The engine exhausted into a regenerator feeding mixed pressure D. C. Turbines, which gave fair economy until high price of labor and coal ran the steam cost to extreme figures. But the main trouble was the inability of the engine to handle the loads imposed by improvements that increased capacity of the mill. It will be noted in sheet showing records of turns per year that capacity had gone up before change was made. To do this some economies were sacrificed and parts of the mill were strained, giving excessive renewal costs.

There were two problems. First, the revision of the mill; second, the proper application of the drive. The mill revision was engineered by the original builders of the mill, in conjunction with the Steel Company's staff, and the drive, finally decided on as electrical, was done in the same way by mill builders, Steel Company, and Electrical Manufacturers. Electric drive was the only one considered, as previous to this time it was decided to electrify the whole plant. As this is not a discussion of steam versus electric drive, it is only necessary to say that a scarcity of water, and long haul of coal or oil fuel, and no blast furnaces, made additional steam generators, and consumers, a too expensive proposition, and will remain so as long as the central station will furnish power at a reasonable rate.

All changes were not made at the time needed, as the heating furnace known to be small, has not yet been remodeled, though plans are all complete to do so. This limits the full realization of the benefits that can be obtained from the revised mill. This furnace, which is producer gas fired, will be enlarged the end of March, 1925, and the mill should then be in shape to produce a much larger tonnage.

Figure 2 gives the revised mill. The same roll stands are used as in the old installation, except that No. 5 rods are not looped in No. 7 and No. 8 stands, but are finished in a 3 stand continuous mill. These finishing stands are 8" rolls, with housings and pinions of the latest type. Pinions have cut helical teeth of fine pitch, with both necks and teeth lubricated by forced feed oil circulating system; 1½"—30-foot billets are used on rods, double-stranded through roughing, and repeaters used between stands Nos. 6 and 7, 8 and 9, 10 and 11. This gives three catchers on the mill. Some trouble was expected with repeater at Nos. 6 and 7 and loop at Nos. 11 and 12, due to speed regulation changes between motors, but so far results have been good and no special change has been made in regulating apparatus.

For bars and flats single stranding is used through roughing and finished in same passes as on old mill. A large part of the output is concrete reinforcing bars, which is finished in same stands as corresponding sizes of plain bars.

In electrifying the drive it was decided to divide it into three parts. One motor driving through enclosed, helical reduction gearing, replaced engine and shaft to drive the six roughing stands. One motor, directly coupled to the second pulley shaft, and by special take-up pulleys for belt, drives the three shafts as in the old mill. This is what is known as the Intermediate drive. While the third or Finishing motor, drives the three last stands through a special pulley and belt set and pinions for each stand. No. 12 stand of rolls can be connected either to the Finishing or the Intermediate motor, as desired. Rod reels are driven by a belt from Finishing motor pulley shafts.

The main drive pulleys are all heavy and run at high speed. In the newer installation they were given a running balance, and the ends sealed with boiler plate to keep out accumulations of dirt. All pulleys have ring oiled bearings, and forced feed oil lubrication from a common gravity system, where oil is cleaned and filtered. This same system oils the gear bearings for Roughing mill shafts and the bearings on the Roughing reducing gear set.

Maximum speeds of rolls were increased about 30 per cent and driving power increased to give an estimated increase of about 50 per cent in capacity. Since such a variety of sizes are rolled. A wide variation of speed is required, the highest speed being a little more than 2½ times the low speed.

Induction motors with speed regulating apparatus were at first considered, due to high overall efficiency; but wide speed range requirement, as well as simplicity of motors and control equipment finally settled the drive for direct current. As the slower speeds are used for bars, where a single strand is in the mill at one time, and the number of elongations are few, the loads are low theoretically. Indicator tests on engine over a period of time also gave low loads at the speeds used on larger bar sizes. By this data, it was

*Elec. & Mech Engr., Atlantic Steel Co., Atlanta, Ga.

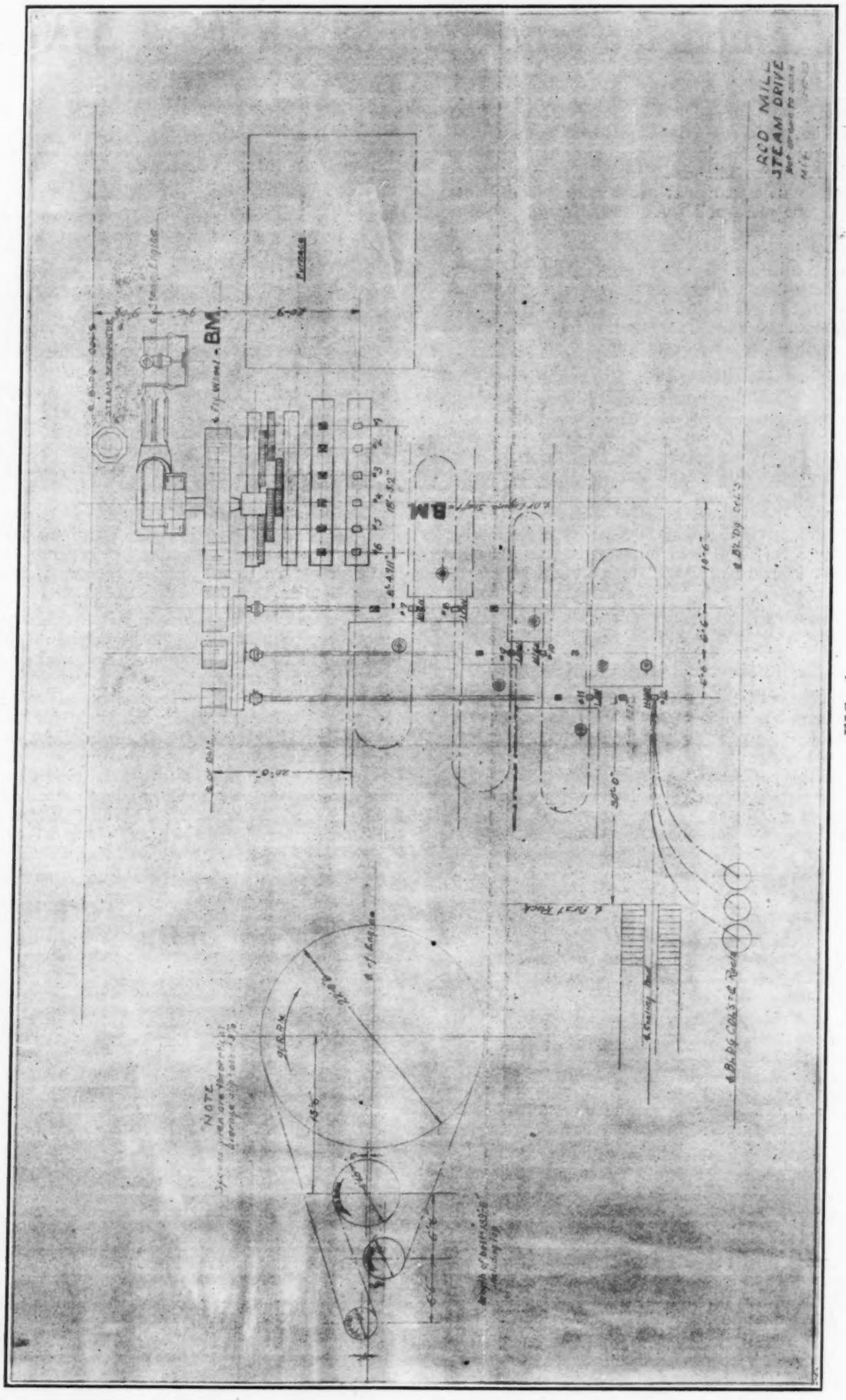

FIG. 1

determined that motors of constant torque characteristics would fill the requirements.

The drive as installed consists of a 3720 H. P., 2200 volt, 60 cycle, 720 R.P.M. synchronous motor, 80 per cent leading P. F., direct connected on common bed plate to two 1280 K.W. 600 maximum volts direct current generators. The synchronous motor has its ventilating air intake enclosed and gets its air supply through a duct in the base leading to the outside air This duct has several meshes of screen to keep out the larger particles of dirt. No forced ventilation is used, the rotating field fans provide sufficient suction. The two generators as well as the three mill motors are self-cooling in the conventional manner, but openings in the foundations have been provided in case forced ventilation should be needed. This precaution was the result of experience with trouble due to extremely long hot spells in this climate, with heavily-loaded apparatus. However, no need has shown up for extra ventilation as yet after two years' service, as the motor house is ventilated at both gables with motor-driven exhausters.

The Roughing and Finishing motors rated at 975 to 375 H. P., 650 to 250 R.P.M. and 975 to 510 H. P. 865 to 450 R.P.M., respectively, are driven by one generator, while the Intermediate motor, 1840 to 710 H. P., 575 to 220 R.P.M., is driven by the second generator. All motor voltage rating is 600 volts maximum, decreasing with speeds. These mill motors are of heavy mill construction with interpole fields and in one case compensating windings. Each has a heavy thrust bearing on the mill side, the pedestals being excep-

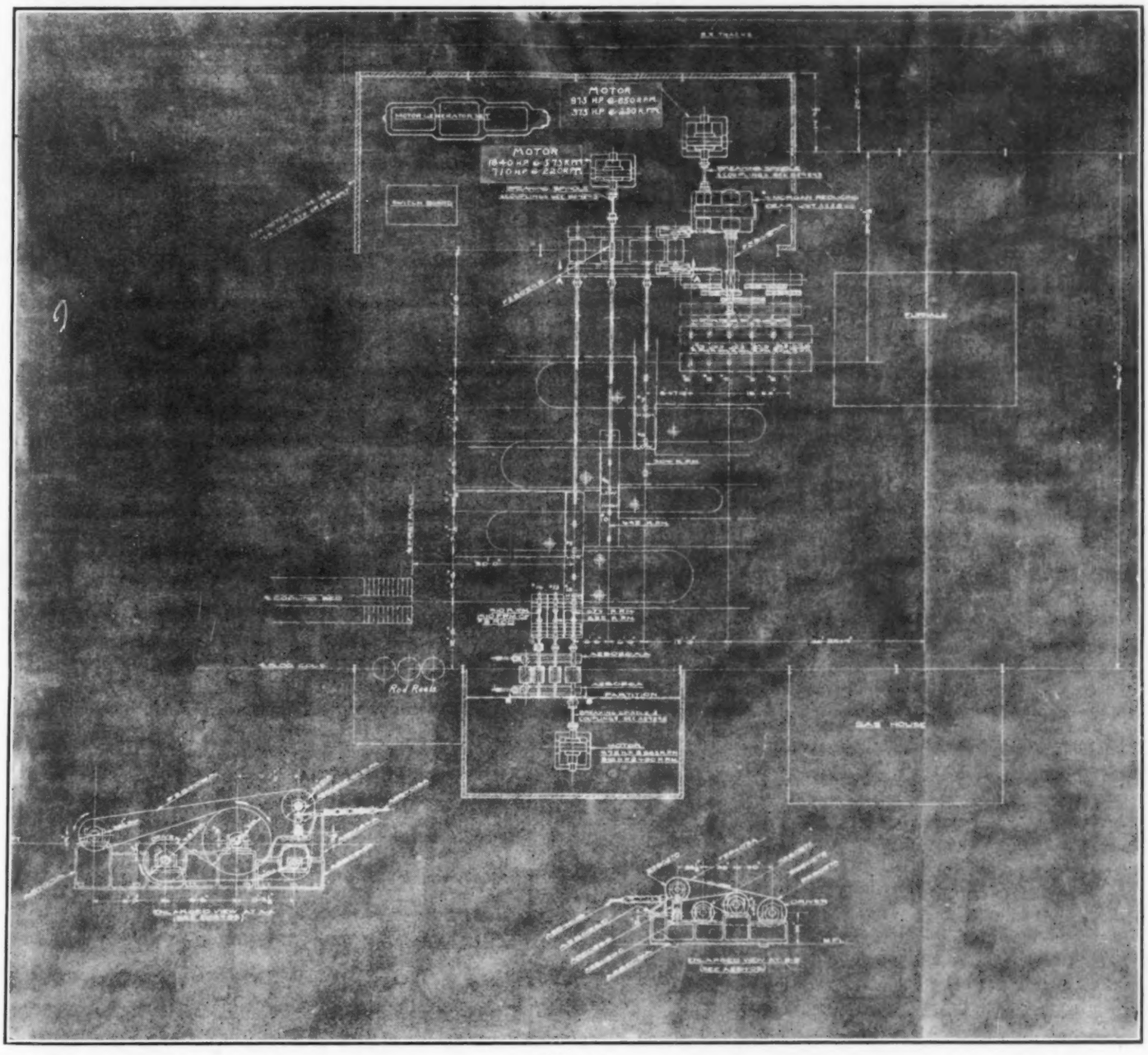

FIG. 2

tionally low to give additional strength. There are no particularly exceptional features except that each motor has a single pole, double throw switch mounted on the field frame, which switch can be thrown to cut out the series field and give only the separate excitation. It was found that after adjusting the shunts

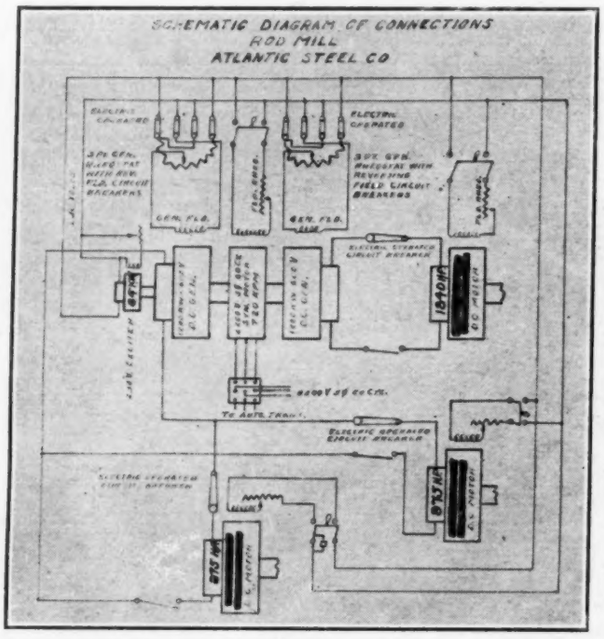

FIG. 3

on series fields that a slight amount of compounding gave a more stable operation than the straight shunt, or separately excited field alone.

Speeds are regulated by varying the voltage of the generators, which are separately excited from a common exciter for fields of synchronous motor, mill motors and generator fields. This exciter is 64 K. W.

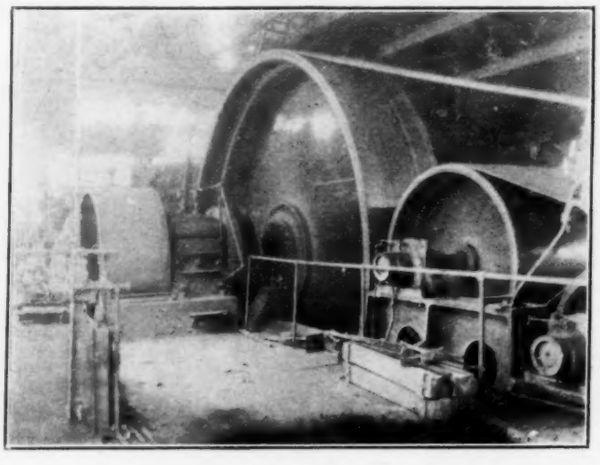

FIG. 4

230 volts, so that mill current may be used in case of exciter failure. Current for operating contactors and electrically operated circuit breakers is also furnished by this exciter. The generators also have series fields for compounding and are equipped with two single pole knife switches on the side of field frame. Three positions of switches; both closed; one open, and both open; shunt out portions of the series field current, so that approximately the correct ratio between shunt or separately excited fields and series fields is obtained at the various excitations for different voltage. This gives an approximately flat voltage regulation at all loads and speeds. About 15 per cent speed vari-

FIG. 5

ation is obtained by field rheostats in each mill motor field. It was found that motors of 1100 H. P. on Roughing and 1700 H. P. on Intermediate would be more in accordance with the load, though up to date no overloading has been encountered on the Roughing motor.

Fig. 3 is a Schematic diagram showing the general plan.

The Roughing and Intermediate motors, and motor generator set, with control, are housed in a steel building on one side of the mill, while the finishing motor is in a separate steel structure on the opposite

FIG. 6

side. All control is in the first or main motor room, and is in two divisions. First, a switchboard structure with manual oil switch starter for synchronous motor, equipped with necessary indicating and recording instruments, and a curve drawing meter giving total K. W. load of the synchronous motor. In line with this is a four-panel switchboard, containing all switches,

circuit breakers, field switches and protective apparatus for D. C. generators, motors and exciter. Second, a benchboard control board on a pulpit overlooking the mill. Here is controlled the polarity and voltage of the generators, the closing switches, on the motors, direction switches, and field rheostats for speed regulation. This control is accomplished with push buttons for the field switches, generator voltage, and voltage polarity switches, and small hand wheels for field rheostats. Suitable interlocks both on benchboard and main panel, prevent wrong or dangerous operation.

Here, also, are located volt meters for generator voltages which also give a measure of the motor speed, and ammeters for each of the motors, so that operator has constant knowledge of conditions of load and speed, as well as a view of the operations of the mill. There is no control in the finishing motor house, only the armature and field wires being carried into it from the main control panel. The wiring is all carried in fibre duct set in concrete. High voltage A. C. is wired with varnished cambric braided, and D. C. with rubber-covered cable. The control wiring is rubber covered in rigid iron conduit. There has never been any trouble with dampness in this installation.

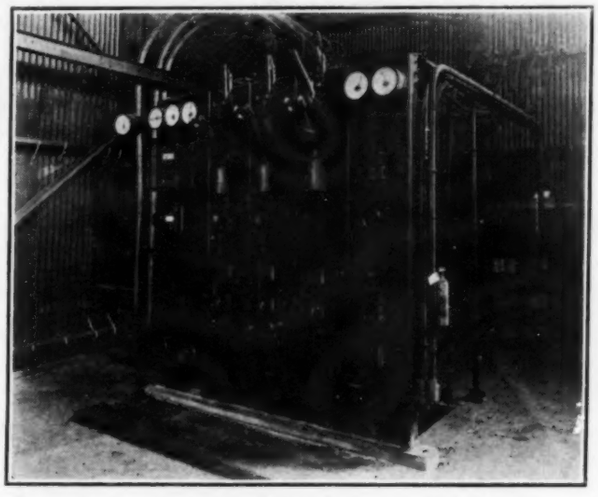

FIG. 7

Power, most of which is hydro-electric, is purchased from a central station. The use of a leading power factor synchronous motor was necessary, not only because of the demand of the power company, but also on account of the better voltage maintained at the end of a four-mile transmission line. This motor is not automatically regulated, but works in conjunction with other synchronous motors on D.C. motor generator sets that have Tirrill regulators for maintaining constant voltage. The Rod Mill motor field excitation is usually set at about 95% leading power factor at 2500 K.W. load. This power factor correction and voltage maintenance is very important when the large induction motors on reversing Blooming Mill and other rolling mills are running.

Figure 4 shows an old engine and pulleys on what is now the intermediate drive. Figure 5 shows the motor generator set. Practically the same pulleys as shown in figure 4 are shown in figure 6. Figure 6 shows the roughing and intermediate motors and reduction gears. Figure 7 is the switchboard. Figure 8 the control panel and figure 9 the finishing motor.

Some of the results obtained were as were expected, while others, not thought of, were obtained. In the old installation all groups of rolls being tied together by the engine with a definite ratio to each other, there were certain points which held up production because some sets of rolls could not take steel as fast as it could be fed from the preceding rolls. Now there are three divisions of rolls and the speed between these

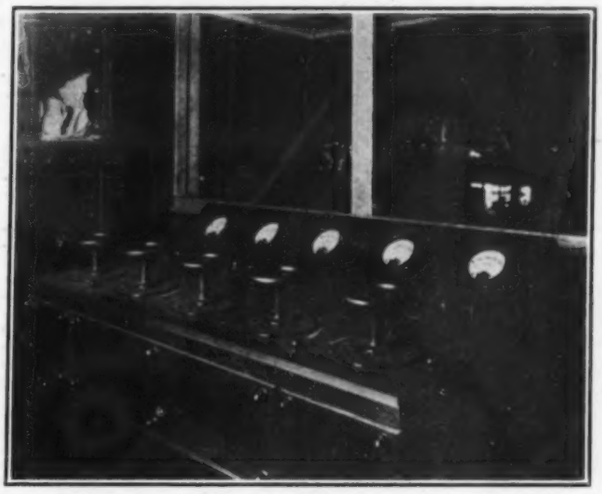

FIG. 8

divisions can be varied with the motor so that the lagging or choked passes are speeded up to keep up with the rest of the mill. In rolling bars the speeds on engine were low and the power ample, and it was not thought that motors could help in this rolling, yet the ability to increase or regulate certain groups of stands separately has increased this capacity, though some of the rolls are running at the same speed as used with

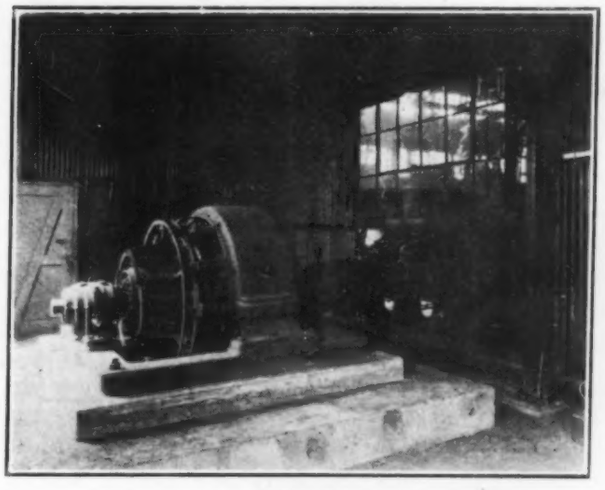

FIG. 9

the engine, in other words the mill can now be filled up. It has been found that the quickness with which the motors may be stopped and reversed, and the fact that rolls are in groups, also saves a great deal of time. In the old mill the engine had to be stopped, and the whole mill moved when it was in motion. Now in case of trouble, one set of men can clear up trouble, with one motor backing up or running slow as desired, while

other men can be making adjustments or changes in the two other groups without interference.

Figure 10 is a tabulation of H.P. and R.P.M., etc., on rolling various sizes of rods and bars. The figures given are average readings taken at several different dates with varying conditions. Horse power is electrical or volt-amp. input to mill motors. Total input to mill is shown by the chart for K.W. input on synchronous motor. Figure 11 is a curve taken when rolling No. 5 rods. Figure 12 is a curve showing a run on more than one size of bars. It will be noted that the load curves on rods show more power as an average at one time than another. This is due to the variation in heating due to too small a heating furnace. It is found that with a furnace full of hot billets the production is good for about an hour or two and then slows down to a speed that will allow steady heating.

ROD AND MERCHANT MOTORS HORSE POWER
IN ELECTRICAL IN-PUT TO MOTOR

PRODUCT	ROUGHING MOTOR H. P. MAX LOAD	H. P. AVER. LOAD	R.P.M.	INTERMEDIATE MOTOR H. P. MAX. LOAD	H. P. AVER. LOAD	R.P.M.	BILLETS
#5 Rod	1029	692	514	1485	934	505	1-1/2" Sq.
1/4" Rod	785	524	469	1489	732	438	1-1/2" "
9/32" P.R.	441	337	481	492	295	401	1-1/2" "
1/8" "	406	272	376	749	454	358	1-1/2" "
7/16" "	391	329	420	632	394	316	1-1/2" "
1/2" "	406	302	380	393	370	370	1-1/2" "
5/8" "	326	278	395	482	359	325	1-1/4" "
3/4" "	326	290	386	525	319	310	1-3/4" "
3/8"R.Cor.	364	286	408	636	396	362	1-1/2" "
1/2" "	419	341	369	660	382	301	1-1/2" "
5/8" "	403	283	449	644	451	276	1-1/2" "
3/4" "	626	391	421	525	309	314	1-3/4" "
1/8" "	406	293	337	379	235	276	1-3/4" "
1" "	441	285	360	312	232	275	1-3/4" "
1-1/8""	394	332	426	431	289	320	2-1/8" "
3/8"S.Cor.	323	262	341	527	381	285	1-1/2" "
1/8" "	342	271	414	725	424	294	1-3/4" "
5/8" "	279	257	300	580	238	235	1-3/4" "
3/4" "	597	356	418	499	337	330	1-3/4" "
1" "	732	383	408	472	248	284	2-1/8" "
1-1/8""	377	283	366	403	276	270	2-1/8" "
1-1/4""	304	268	333	410	295	244	2-1/8" "
	FINISHING MOTOR						
#5 Rod	824	652	709				

FIG. 10

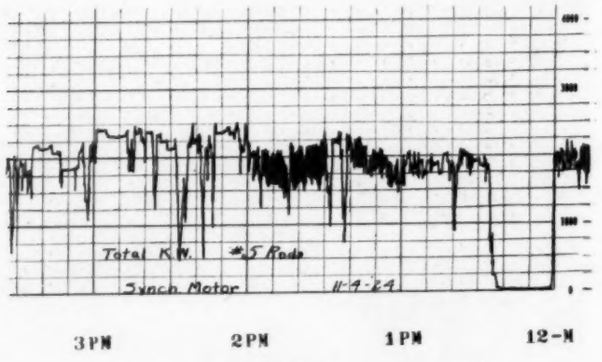

FIG. 11.

This will continue at about the same pace until some delay allows billets to heat, then the power consumption drops off. The maximum power input generally comes with the coldest steel, but this is at reduced tonnage, which gives a high K.W. consumption per ton. Figure 13 is an ampere chart on finishing motor, rolling No. 5 rods.

Kilowatt hour consumption per ton of various sizes is given:

Average K.W. Hr.	Consumption per ton of prod.
No. 5 Rods	151 K.W. Hrs. 1½" Billets
¼" Rods	135 K.W. Hrs. 1½" Billets
9/32" P. Round	116 K.W. Hrs. 1½" Billets
⅜" P. Round	108 K.W. Hrs. 1½" Billets
7/16" P. Round	100 K.W. Hrs. 1½" Billets
½" P. Round	102 K.W. Hrs. 1¾" Billets
⅝" P. Round	73 W.K. Hrs. 1¾" Billets
¾" P. Round	52 K.W. Hrs. 1¾" Billets
⅜" R. Corr. Bar	106 K.W. Hrs. 1½" Billets
½" R. Corr. Bar	74 K.W. Hrs. 1½" Billets
⅝" Rd. Corr. Bar	71 K.W. Hrs. 1½" Billets
¾" Rr. Corr, Bar	61 K.W. Hrs. 1¾" Billets
⅞" Rd. Corr. Bar	43 K.W. Hrs. 1¾" Billets
1" Rd. Corr. Bar	42 K.W. Hrs. 1¾" Billets
1⅛" Rd. Corr. Bar	64 K.W. Hrs. 2⅛" Billets
⅜" Sq. Corr. Bar	79 K.W. Hrs. 1½" Billets
½" Sq. Corr. Bar	67 K.W. Hrs. 1½" Billets
⅝" Sq. Corr. Bar	56 K.W. Hrs. 1¾" Billets
¾" Sq. Corr. Bar	45 K.W. Hrs. 1¾" Billets
1" Sq. Corr. Bar	50 K.W. Hrs. 2⅛" Billets
1⅛" Sq. Corr. Bar	47 K.W. Hrs. 2⅛" Billets
1¼" Sq. Corr. Bar	43 K.W. Hrs. 2⅛" Billets

This figure on rods is higher than was expected and is in part due to design of mill giving so many long loops that allow cooling of steel and in part to the inadequate heating facilities which not only increase the power due to reducing relatively cold steel, but also

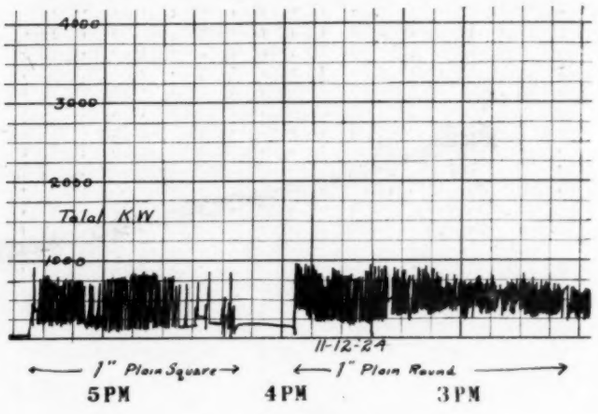

FIG. 12.

decreases the production during a turn which automatically increases the consumption per ton. It is expected to materially decrease the K.W. hour per ton of rods when new furnace is installed. For bars, not much is expected except on certain sizes that now are giving trouble with spotty heating.

Originally built to roll 60 tons per 12-hour turn, the mill was increased until it was averaging over 100 tons per turn, monthly average. All records have been broken on No. 5 rods and a great many on bars. As an example, taking the previous record on steam mill as basis average product per turn yearly, starting with 1913 as 100 per cent; 1914, 93 per cent; 1915, 103 per cent; 1916, 97 per cent, 1917, 105 per cent; 1918, 107 per cent; 1919, 101 per cent 1920, 99 per cent, 1921, 109 per cent, 1922, 119 per cent; 1923, 122 per cent, and 1924, 126 per cent. Or take best hours. After change, it is 31 per cent better than previous record. Best turn records have been broken since the change as follows: Old drive, 100 per cent; new drive 1923, 111

per cent; 1923, 114 per cent; 1923, 117 per cent; 1924, 122 per cent; 1924, 126 per cent. For all product of the mill; all size rods, bars and flats, the average product per turn for a month is 18 per cent better than all previous records before mill change.

One of the greatest benefits derived from the change of drive, is the reduction in maintenance cost.

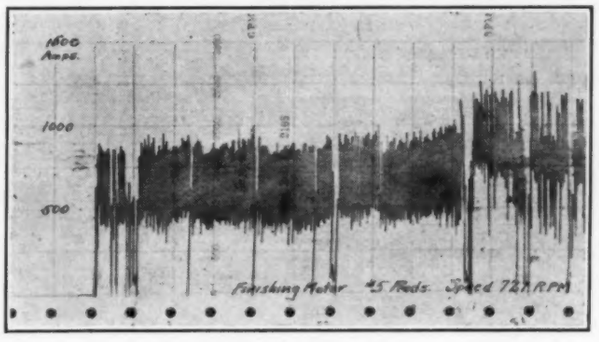

FIG. 13.

With due recognition of the fact that the electrical equipment is new (2 years old) and should not need extra repairs, the upkeep is very much less than with the engine drive, and the number of men needed to keep up the equipment is less, while supplies and lubricants are practically nothing compared with the engine.

At present the cost per ton for repairs, supplies, etc., of the electric drive is not one-half of the average cost for same on the old drive, while the one item of belt alone, having the horse power it is required to transmit, reduced by driving one of its pulleys directly with a motor had reduced belt cost over 80 per cent. These figures represent two years on new mill and ten years on old mill.

It is a hard matter to make real comparisons of cost on account of the out-of-proportion dollars and cents costs during and following the war. However, in this case, the cost of power shows actually less than the old drive, both since and during the war. Of course the years 1918 and 1919 and 1920 are much higher, while the years before this the costs are averaging about even, sometimes lower and sometimes higher.

The figures for this are a combination of cost of steam, water, and electric power. In the old drive auxiliary electric power formed all the electric charge, and auxiliary steam for producers, etc., was a small part of the steam charge. Now the situation is reversed so that for comparison the sum of the items above is used in both cases. As an example, of the last few years, this cost per ton on rods for 1924 is 4% lower than in 1923, 56% lower than in 1922, and 64% lower than in 1921 and 74% lower than in 1920.

After two years' operation the general opinion is that both mill and drive changes have justified themselves, and in no particular would the old drive be preferable.

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*Synchronous Motor Applications**

By JAMES F. BURKE†

THE subject assigned to me was "Synchronous Motor Applications," but I am simply going to tell you about synchronous motors and some other forms of motors and leave the applications to the engineers here this evening, who are much more conversant with applications of motors than I am. My duty as I understand it this evening, as well as my pleasure, is to provoke a discussion on the subject of synchronous motors.

Of course, there is a large variety of synchronous motors, but there is only one group that we can touch on this evening. The other group, which we won't try to discuss in detail, is the group of synchronous motors for the purpose of transmitting synchronous movement.

I might say, as a matter of passing interest, that during the World War the guns of the battleships of the British Navy and of the United States Navy, were controlled by synchronous motors. The observations of the range on the enemy were made from towers on the ships and the indications of range were transmitted to all the guns by synchronous motors. In this application, of course, the important feature was absolute transmission of motion without any variation from the true angular position of the sending apparatus. In other words, these motors acted as a gearing system to gear the indications taken by the observers, to each gun, so that each gun would be brought to the proper elevation, training, etc. We will not have time to discuss that class of synchronous motor tonight.

In taking up the question of motors for the general power applications we have, in addition to our old friend the direct current motor, the first type of induction motor, viz., the squirrel cage induction motor, and we have the slip-ring induction motor, the synchronous motor, the super-synchronous motor and the synchronous induction motor, each having its own qualifications and applications.

In order that we may be all thinking in the same terms, I am going to ask your indulgence in allowing me to take up some of the elementary features of alternating current motors. Most of this is old to all of you and all of it is old to most of you, but in order that we may be speaking the same language, I am going to tune in by passing over quickly a little of the history of the alternating current motor.

The particular feature of difference between the synchronous motor and the induction motor that concerns most of us here this evening is the fact that the synchronous motor may be adjusted so that the amperes are equal to the watts input divided by the volts, as in the case of direct current motors, but of course with proper consideration of the number of phases, but the induction motor, even when operating at full rated load, requires from 10 to 20% more amperes, due to the so-called power factor.

*Presented at Cleveland, October 11, 1924.

†President, Burke Electric Co., Erie, Pa.

Also, there are many mechanical qualifications of synchronous motors which make them much more suitable for many applications than any type of induction motor. For example, in the case of compressors where a motor is placed between two cylinders, there is an advantage in being able to split the whole motor horizontally, and the synchronous motor lends itself to that mechanical construction much more conveniently than an induction motor. Also, the synchronous motor generally has a larger air gap, and that is a great mechanical advantage in many applications and is often the deciding point in the choice of motors. However, the point of greatest importance is in its power factor.

I am going to lead up to this question of power factor by showing a few lantern slides relating to motor history.

In all curves and figures which will be shown we will express mechanical power in terms of kilowatt output instead of horse power, as this is more convenient in expressing conversion factors or efficiency. For example, one kilowatt electrical input resulting in one kilowatt mechanical output would mean a conversion factor of one or, as we now express it, "100% efficiency."

The custom is to convert horse power into kilowatts by multiplying by .746 and this frequent arithmetical calculation can be eliminated by considering kilowatt output instead of horse power.

The English unit of horse power was established so long ago that it has been thought almost heresy to question the scientific basis of it.

History indicates, however, that the foundation of this unit was not very scientific. It seems that when James Watt invented the steam engine he had to adopt some basis of expressing the power of his steam engine, and the only basis of comparison available seemed to be to compare with what a horse could do. An experiment was made, which is recorded as follows:

A horse weighing 1,200 pounds, pulled a canal boat 20 miles in 8 hours, which figures out 220 feet per minute. The experimentor estimated that the pull on the tow line was about a hundredweight, which, in English weights and measures, is 112 pounds. Multiplying the 220 feet per minute by the 112 pounds gave 24,640 foot pounds per minute. This particular horse was considered above the average, in fact, a very powerful horse, and so 10% was taken off to reach a figure representing an average horse, resulting in approximately 22,000 foot pounds per minute. Then Watt took into consideration the fact that he was dealing with an incredulous public, and that it was better to be conservative and add a margin of safety, so he added 50% to the 22,000 and thereby established the unit of 33,000 foot pounds per minute as equal to one horse power.

If he had added 100% instead of 50% we would have had with us today the unit of horse power, of 44,000 foot pounds per minute, which happens to equal one kilowatt and calculations of power in connection with electric motors would have been thereby much simplified. We would have had no use for the 746 watts per horse power calculation, as this would become 995, or for all practical purposes, 1,000, or 1 kilowatt.

Table No. 1 shows an illustration of a typical direct current motor of one mechanical kilowatt output, or 1 1-3 H.P.

Table No. 1

DIRECT CURRENT MOTOR

1 1/3 Horse Power or 1 Mech. Kilowatt Power

Mechanical Power Delivered at shaft	Electrical Power Deleivered at Motor	Conversion Factor
None (Belt off)	.15 Kilowatt	0
.25 Kilowatt	.41 Kilowatt	.61
.5 Kilowatt	.67 Kilowatt	.74
.75 Kilowatt	.96 Kilowatt	.78
1.00 Kilowatt	1.25 Kilowatt	.8

ILLUSTRATION

1.25 K.W. Input x Conversion Factor .8 = 1 K.W. Output

Column one shows the mechanical kilowatts delivered at the shaft under the various conditions of no load (belt off), one-quarter load, one-half load, three-quarter load and full load of one kilowatt.

The next column shows the electrical input delivered to the motor in kilowatts.

The third column is the mechanical kilowatts delivered at the shaft divided by the electrical kilowatts delivered to the motor, resulting in the "conversion factor" of electrical into mechanical power in this typical motor. As an illustration, with one mechanical kilowatt delivery and 1.25 electrical kilowatts input, we have a conversion factor of .8, or in popular language —80% efficiency.

In the early history of the induction motor it was discovered that the current required was much in excess of what would be expected by comparison with the direct current motor, and Table No. 2 is a typical case of an early induction motor of one mechanical kilowatt output, which is directly comparable with the direct current motor just referred to.

Table No. 2

PERFORMANCE OF INDUCTION MOTOR

Mechanical Power Delivered at shaft	Kilowatt Meter	Kilovolt Ameres	Factor by which Kilovolt Amp. must be multip. to get true Kilowatt	Power Factor
None (Belt off)	.15	.62	.24	24%
.25	.41	.76	.54	54%
.5	.67	.98	.68	68%
.75	.96	1.27	.75	75%
1.00	1.25	1.6	.78	78%

It will be observed that Column one is the same as in the case of the direct current motor. Also column two, which shows the reading of a kilowatt meter, is the same as Column two in the direct current motor, showing electrical power delivered to the motor. Column three is the kilovolt amperes or the volts times amperes divided by 1000. In the case of direct current Column two and Column three would be alike and the difference between these two columns first came to attention in connection with induction motors and was one of the unexplainable phenomena in connection with early induction motor development.

The pioneers of induction motors had, therefore, to take into consideration a factor by which the kilovolt amperes should be multiplied to get the true K.W. and this factor was Column 2 divided by Column 3 and is shown in Column 4. For example, at the condition of

full load or 1 K.W. Mech, delivery the factor is shown as .78 and today we call this 78% power factor as shown in Column 5.

There was considerable mystery about the cause of the increased current or what was then called the useless current of induction motors, but finally the theory of the induction motor was established and it was recognized that the reason why the induction motor as shown in Table 2 required .62 kilovolt amperes running free instead of .15 kilowatts as in the direct current motor was that the induction motor required a considerable magnetizing current. The direct current motor with which all were familiar required only a small amount on direct current for producing the magnetism, whereas the induction motor on account of the magnetism being produced by alternating current required many times that of the direct current motor.

The synchronous motor differs from the induction motor in the fact that it goes back to having magnetism produced by direct current.

One of the simplest illustrations (Table No. 3) of this wattless current or magnetizing current which you may, perhaps, find it convenient to use in explaining power factors to some of the mechanical brothers who are not conversant with electrical problems is this illustration of a storage battery charging and discharging.

Table No. 3

READINGS OF VOLT AND AMPERE METERS

Receiving 100 volts x 10 amperes x 1 hr.
= 1000 volt amp. hrs = 1 K.V.A. hr.

Returning 100 volts x 10 amperes x 1 hr.
= 1000 volt amp. hrs = 1 K.V.A. hr.

Total for 2 hrs 2 K.V.A. hr

READINGS OF WATT HOUR METER

Receiving 1 Kilowatt for 1 hr. (forward)
= + 1 Kilowatt hr.

Returning 1 Kilowatt for 1 hr. (backw'd)
= — 1 Kilowatt hr.

Total for 2 hours = 0 Kilowatt hrs.

The illustration assumes a storage battery of 100% efficiency and shows that it receives a charging current of 10 amperes at 100 volts for one hour and then immediately is discharged back in the Power Company's lines returning 10 amperes at 100 volts for one hour. Therefore, during a period of two hours, there is 10 amperes flowing, but the Power Company has sold no current for the amount which it delivered during the first hour was returned during the second hour.

If, instead of voltmeter and ammeter reading as considered, we use a watt-hour meter, it will be seen that the readings of the watt-hour meter are as in the above tabulation. During the first hour the watt-hour meter would show plus 1 K.W. hour. During the second hour the meter would work in the reverse direction as the flow of energy during that hour would be minus 1 K.W. Thus the algebraic total for two hours is 0 K.W.

In other words, over this long cycle of two hours the average result was no K.W. but 2 K.V.A. In the language of alternating currents there is 2 K.V.A flowing at zero power factor, resulting in zero K.W.

The Power Company's lines have been carrying 10 amperes for two hours, but they get no revenue from same because the current has been furnished at the equivalent of zero power factor.

The foregoing illustration is somewhat comparable with an alternating current of the extremely slow cycle of one complete cycle in two hours. Of course in the alternating current cases these cycles are taking place

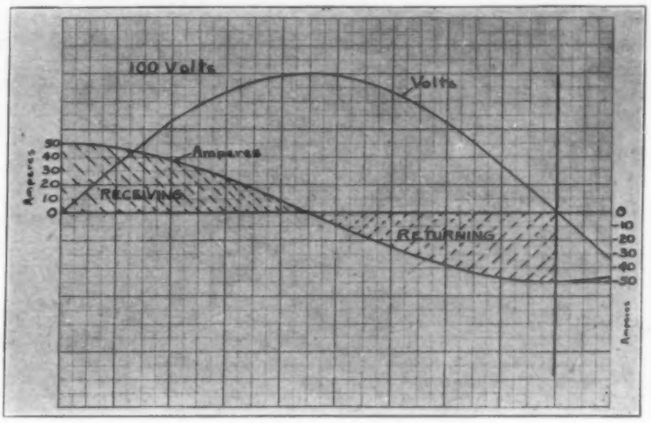


FIG. 1.

at the customary frequency of 60 cycles per second or 25 cycles per second.

If we consider the magnetizing current only of an induction motor the condition is shown diagramatically in Figure No. 1.

The voltage curve shown is a typical alternating current wave starting from zero reaching a maximum and returning to zero, reversing, after which it would repeat the cycle in the opposite direction. The current is shown starting at an assumed value of 50 amperes at the time when the voltage is zero, as with magnetizing currents the current is displaced 90 electrical degrees or one-quarter cycle from the voltage. This curve of amperes, it will be seen, follows the typical alternating current form of wave and reaches zero at the time that the voltage curve is maximum. During this period from the start at 50 amperes to the zero condition, it may be considered that current is being received and is comparable with the charge of the storage battery in the previous illustration. After the current reaches zero it reverses and gradually reaches 50 amperes in the opposite direction. During this period it may be considered that the current is being returned. It will be observed that the shaded area marked "RECEIVING" is above the zero line, and that the shaded area marked "RETURNING" is below the zero line, but of equal area. Therefore, the current returned just balances the current received, so that the net result is zero K.W., although the current has been flowing all the time with a maximum flow of 50 and an average flow of approximately 35.

One of the most difficult problems in connection with "power factor" is to explain it to those who are unfamiliar with electrical engineering. In Figure 2 will be illustrated an explanation of "power factor," which I have found satisfactory in illustrating to non-electrical people and I will now pass it on to you as you, also, may find it a useful way of explaining "power factor" to those unfamiliar with it.

Figure 2 illustrates in the vertical line a building of eight stories, numbered 1 to 8. The horizontal line numbered 0 to 6 represents distance from the building

line equal to the height of each floor. Now if we consider a load of material being transferred from the starting point 0 to the eighth story of the building, this material would first be moved horizontally over a distance equal to 6 and then vertically up a distance equal to 8. The horizontal distance is considered as having

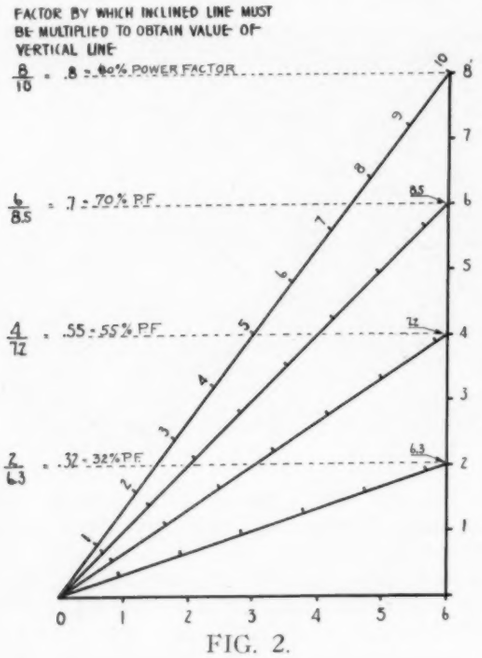

FACTOR BY WHICH INCLINED LINE MUST BE MULTIPLIED TO OBTAIN VALUE OF VERTICAL LINE
5
8/10 = .8 = 80% POWER FACTOR
6/8.5 = .7 = 70% P.F.
4/7.2 = .55 = 55% P.F.
2/6.3 = .32 = 32% P.F.
0 1 2 3 4 5 6
1 2 3 4 5 6 7 8 9 10
8.5
7.2
6.3

FIG. 2.

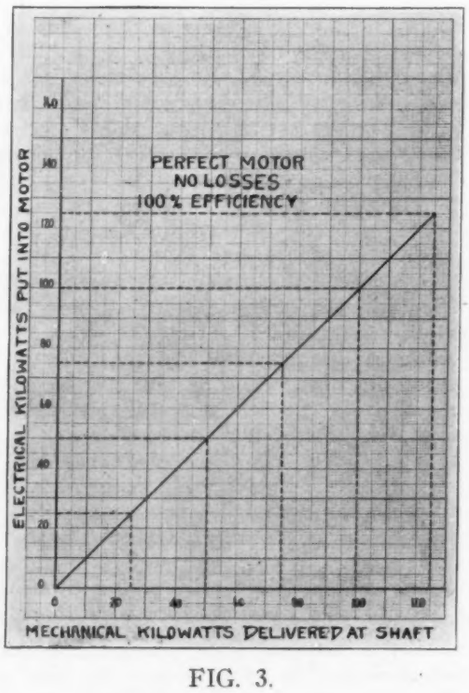


FIG. 3.

no energy stored as there is no elevation of the load carried, and is comparable with magnetizing current. The vertical travel represents actual work and is comparable to energy current.

Now instead of carrying the load horizontally from 1 to 6 and then vertically up to 8, let us assume that it is carried diagonally from the starting point 0 up to 8 along the diagonal line shown. This diagonal line will be seen to have a length of 10 as compared with the vertical height of 8. Therefore, the load is carried over an actual distance of 10, but its effectiveness is simply the vertical height of 8. This means that the diagonal measurement of 10 has only an effectiveness of 8 or an effective factor of 8 divided by 10 equals .8. In the language of alternating currents the power factor is 80%.

Similar illustrations are given with various loads, namely, 6 stories being equivalent to ¾ of the total vertical height and comparable with ¾ load; also 4 stories representing ½ of the total vertical height and comparable with ½ load. Also 2 stories representing ¼ of the total height and comparable with ¼ load. The horizontal travel is the same throughout, namely, 0 to 6. The power factors are shown on the left hand margin of the figure and as will be seen they range from 80% at full load, 70% at ¾ load, 55% at ½ load and 32% at ¼ load.

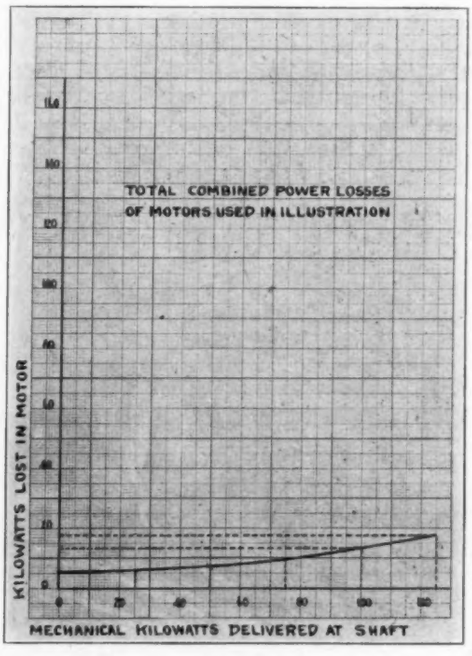

TOTAL COMBINED POWER LOSSES
OF MOTORS USED IN ILLUSTRATION
KILOWATTS LOST IN MOTOR
MECHANICAL KILOWATTS DELIVERED AT SHAFT

FIG. 4.

I have found that this simple explanation often removes a lot of the mystery of power factors.

The central stations at first did not worry about power factors. Then they commenced to realize that the effect of this increased current over lines was something that they had to provide copper for, and machine capacity for, and transformers for, and they were getting nothing for it. They knew they were furnishing more current than they were getting paid for, but the watt-meters installed at their customers' plant didn't indicate it. Later they came to the conclusion that they must establish some basis of charging for this current not recorded on their customers' meters, and hence there has come about a variety of methods by which customers are charged or penalized for "low power factors."

There is so much difference between different plants in the sizes of motors installed that no general rule will apply to all plants, but each must be considered as

a special case. For the purpose of illustration I have assumed a small manufacturing plant in which fifteen motors are installed of various sizes as shown in Table No. 4.

GROUP OF MOTORS IN FACTORY USED IN ILLUSTRATION

5	1 HP	1800	Rev.
3	3 HP	1800	Rev.
2	5 HP	1800	Rev.
2	10 HP	1800	Rev.
2	20 HP	1200	Rev.
1	50 HP	1200	Rev.

Total 134 HP or 100 Mech. Kilowatts

It will be noted that the total rated horsepower of the motors amounts to 134 which equals 100 mechanical kilowatts.

Let us first consider the question of efficiency. If electric motors have an efficiency of 100%, the mechanical kilowatts delivered at the shaft would be the

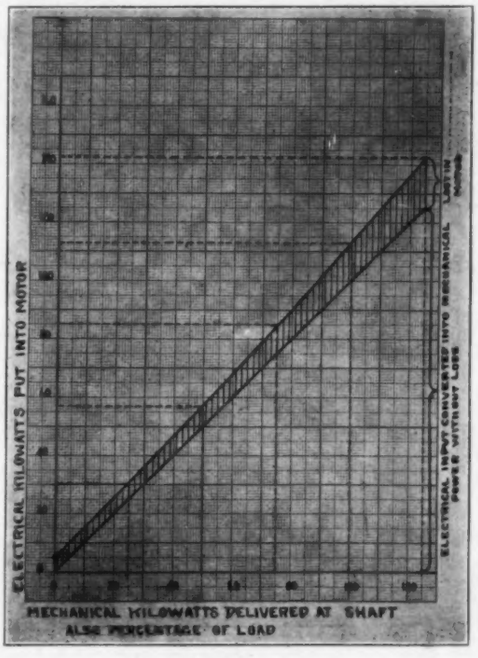


FIG. 5.

same as the electrical kilowatts put into the motor. This theoretical condition is shown diagramatically in the following Figure No. 3.

Referring to this slide it will be seen that at the point in the horizontal indicating 100 mechanical kilowatts delivered at the shaft, a vertical line will intersect a horizontal line drawn from the vertical tabulation of electrical kilowatts put into the motor, showing that under this ideal condition of 100% efficiency the mechanical kilowatts output are equal to the electrical kilowatts input. This chart shows the same condition of output being equal to input at various kilowatts, namely, 100 representing full load, 75 representing three-quarter load, 50 representing half-load, 25 representing a quarter load and 125 representing 25% overload.

We have, however, to take into consideration the losses of energy in the motors in converting from electric power into mechanical power. Figure No. 4 shows the combined losses in the group of motors used in this illustration.

It will be seen that even when no mechanical kilowatts are being delivered at the shaft that the group of motors have a loss of approximately 5.5 kilowatts, and that the losses increase gradually as the load is increased amounting to approximately 13 kilowatts loss when the group of motors are delivering 100 mechanical kilowatts of power at their shafts.

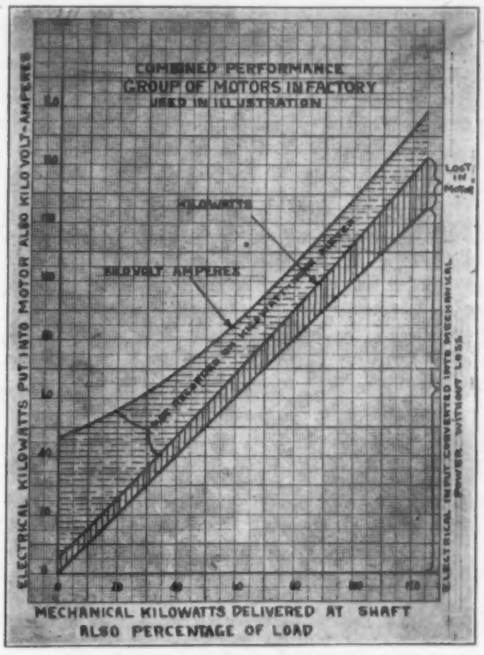


FIG. 6.

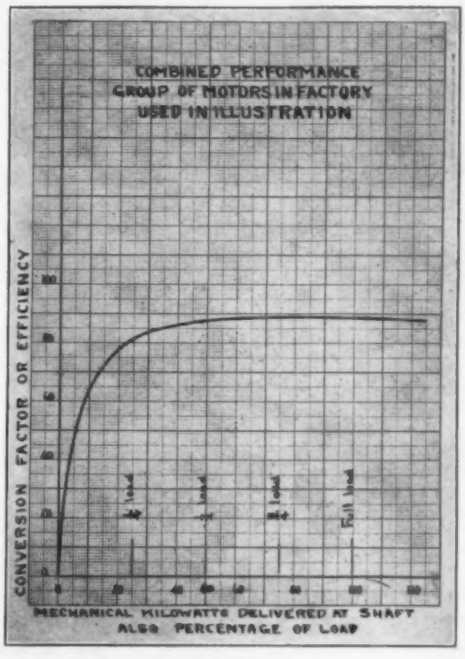


FIG. 7.

If we add these losses to the electrical kilowatts input we get a chart as shown in Figure No. 5.

This chart shows in the lower diagonal line the theoretically ideal condition of 100% efficiency similar to that shown in Figure No. 3 and above this is another diagonal line showing the electrical kilowatts which have to be put into the group of motors including the losses in the motors. The difference between these two lines or the shaded area represents the losses in the motors.

The previous figure represents the losses in the conversion of electrical energy into mechanical and shows the electrical kilowatts necessary for producing various mechanical kilowatts output in the group of motors chosen. Let us now consider the kilovolt amperes instead of the kilowatts. This is illustrated in the following Figure No. 6.

The lowest diagonal line is again the illustration of the ideal motors of 100% efficiency. The next diagonal line represents the actual conditions after considering the losses in converting from electrical into mechanical energy, or the kilowatts input. The highest line represents the kilovolt amperes input. The area shown by the vertical shading represents the energy losses and the area shown by the horizontal shading represents the kilovolt ampere losses which cause the low power factor of induction motors.

It will be observed that with the motors running at no load or with no mechanical kilowatts delivered at the shaft, they are consuming a total of approximately 47 kilovolt amperes, 6 of which represent the

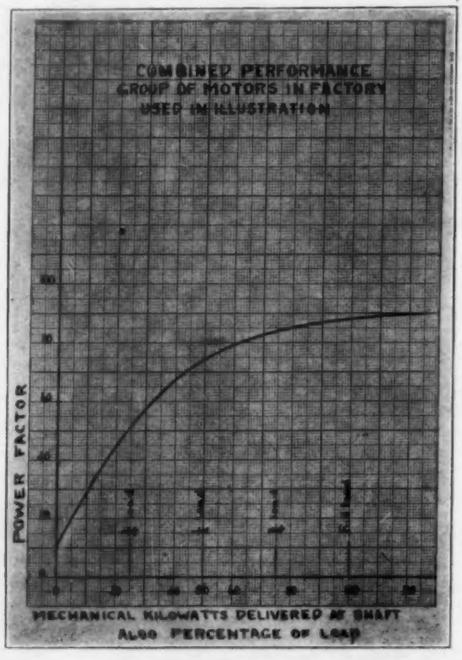


FIG. 8.

losses in the group of motors and the large balance represents the magnetizing current or what is sometimes popularly referred to as the wasted amperes.

It will be observed that this kilovolt ampere loss gets less and less as the load on the motors is increased, which, of course, means that the power factor of the motors improves rapidly with increasing load.

The customary way of showing performance of motors is in the form of an "efficiency curve." The group of motors used in this illustration, taken collectively, have an efficiency curve as shown in the following Figure No. 7.

The shape of this curve is somewhat different from that of any individual motor as it represents the combined curves of all of the motors being used in the illustration.

As we all know the efficiency at no load is zero. It will be seen from the curve that the efficiency rises rapidly and reaches 78% at 20 kilowatts output or one-fifth load. At 25 kilowatts output, or one-quarter load,

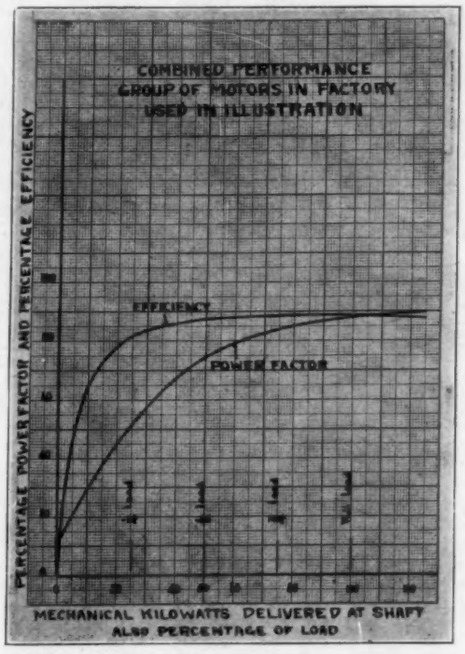


FIG. 9.

the efficiency has reached 81%. At 50 kilowatts output, or one-half load, the efficiency has reached nearly 88%. At 75 kilowatts output, or three-quarter load, the efficiency has reached 89%, and is the maximum of the curve. At 100 kilowatts output, or full load, the efficiency is slightly on the downward path, having a value of approximately 88%.

If we express power factor in the same form of a curve as we have just expressed efficiency, we will have a condition for the group of motors referred to as shown in the following Figure No. 8.

It will be noted that the power factor is extremely low at no load and increases gradually to 74% at half load and 84% at three-quarters and 88% at full load.

In Figure No. 9, we have shown the curves of efficiency and power factor for the group of motors referred to and it will be noted that although the efficiency is high over a considerable range of load, that the power factor drops off rapidly as the load departs to lower loads than the full rated load of the motors.

The Power Companies throughout the country are studying the various ways of charging properly for the effect of low power factor. Some cities have not yet started making a charge for this wattless current, but many companies have been charging or penalizing for poor power factor for some time and thus are getting paid for the currents flowing over their power lines and supplied by their generating plants but which has

not been recorded on the kilowatt hour meters of their customers.

Figure No. 10 happens to show the basis of charging for power factor by the Cleveland Illuminating Company.

The actual schedule of the Cleveland Illuminating Company shows a bonus when power factors are maintained above a certain point, and a penalty if power factors fall below another certain point, but in order to illustrate the matter better I have shown everything as

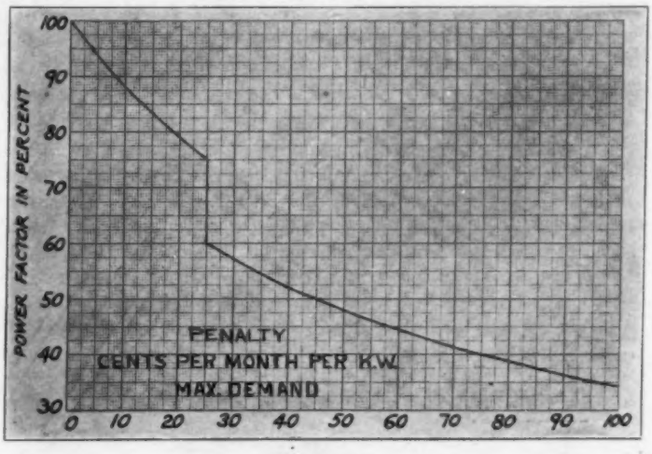


FIG. 10.

a penalty, starting with the net amount resulting from taking advantage of the maximum bonus.

It will be seen from the curve that in the range of power factor between 60% and 75%, the penalty for these power factors is 25c a month per kilowatt or $3.00 per kilowatt maximum demand per year.

Now, if a plant operating at power factors between 60 and 75 of the power supply of the Cleveland Illuminating Company, should bring its power factor up to 100% by installing some synchronous motors, it would make a saving of $3.00 per kilowatt maximum demand, and this saving would pay for the synchronous motors, in most cases, in from two to three years.

As an example, if you consider synchronous motors at a cost of about $9 per kilowatt, you find that at 25c a month, $3 a year, divided into the $9 per kilowatt of original cost of the motor, the saving would pay for the cost of the new synchronous motors in three years. So that the question of the synchronous motors becomes of vital importance from the financial standpoint.

We all know as long as induction motors are used without any synchronous motors or any other means for compensating for the wattless current, we must have a power factor less than 100%, and we must be using excess current from our own central stations or from the central stations from which we purchase current, and there must be an economic loss in so doing.

The first partial remedy is to improve the power factor of the induction motors. Now the power factor of the induction motors as we all know falls off very fast with load, and so the obvious remedy which everybody has been practicing more or less for the last few years has been to operate their motors nearer full load rating than they have in the past. In many plants where they have been operating in the class of 60 power factor it is possible to bring the power factor up to 75 or 80, simply by redistribution of the motors and seeing that all motors are operating at as near as possible full rated load.

Another practice which will improve power factors is to use motors of a higher power factor where some of the characteristics of general purpose motors are not needed, or to be specific, the general purpose motor of today—stock motor—is made so that it will have a heavy starting torque to meet the worst condition that it may unexpectedly meet with. Now, if instead of going to that degree of standardization some special motors are used, such as for operating fans, blowers, etc., where the starting torque may be very much less, those motors can easily have their power factors improved compared with the higher torque motors by four or five per cent.

So that another direction of improvement is to classify motors in the various characteristics of starting torque, etc., and only use high starting torque motors in cases where they are needed. Get a little bit away from too much standardization and choose motors for light starting duty, so that these motors will have the highest possible power factor.

It is quite surprising how much can be done in that direction, the sacrifice, of course, being that you may have different kinds of ten horsepower motors

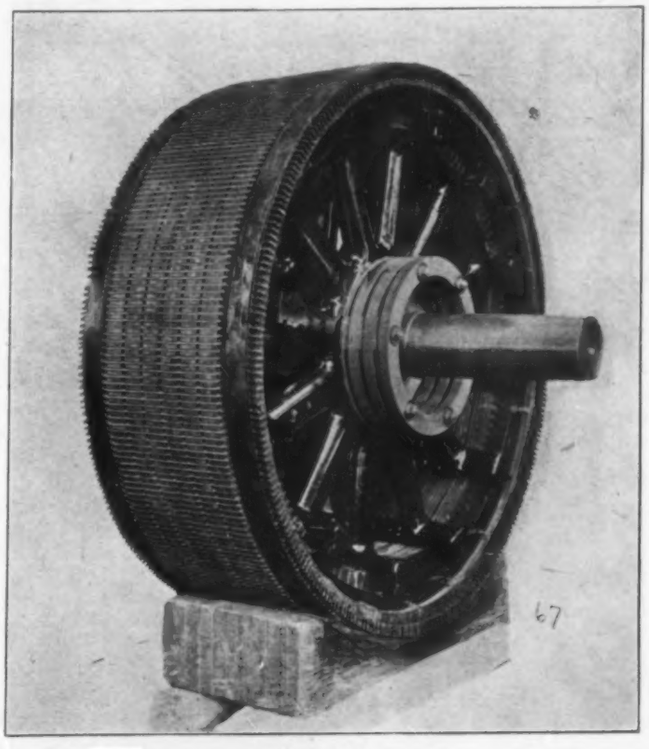


FIG. 11.

in your plant of different kinds of fifty horsepower motors in your plant, some suited for high power factor light starting duty and some for heavy starting duty with necessarily lower power factor.

Of course, the ideal induction motor, the short circuit motor, has the great advantage of simplicity—no brushes, no collector rings, and minimum of service requirement. However, when such motors are used for heavy starting torque work the price paid for the simplicity is somewhat lower power factor and the next

step in the direction of improved power factor is to use more slip ring motors, and to get this properly before you, I will simply visualize a few slip ring motors by means of slides.

Figure No. 11 is a typical slip ring stator. Of course, it is the same for short circuit motor.

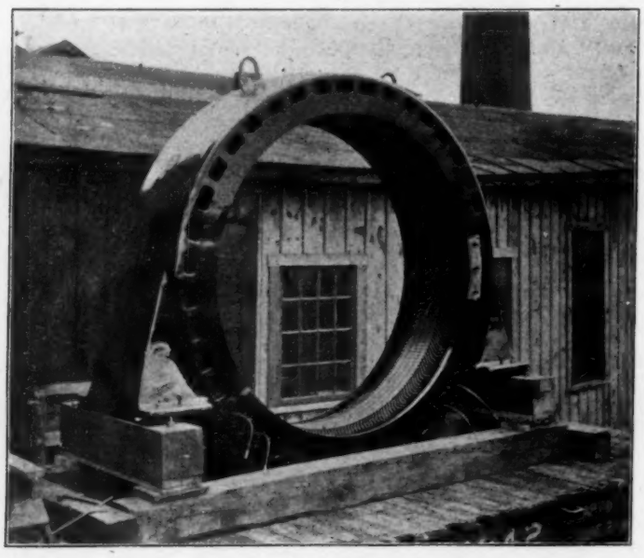


FIG. 12.

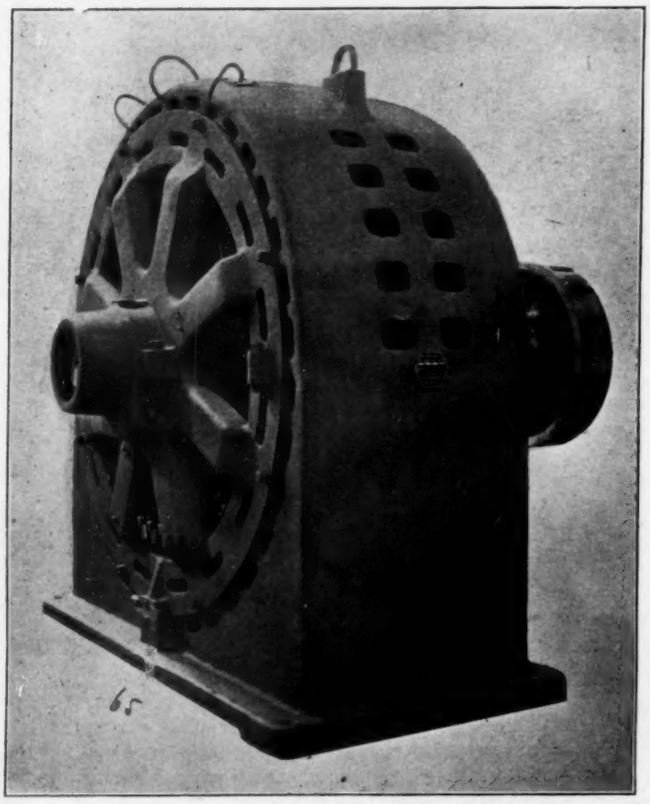


FIG. 13.

Figure No. 12 is a typical slip ring rotor. It happens to be a 400 H.P. motor.

Figure No. 13 is the complete slip ring motor. The slip rings are hidden by the bearing bracket.

Figure No. 14 is another well known means of improving power factor. In cases where the load is extremely fluctuating, where you have heavy peaks, instead of having a motor of the same capacity as the generator and thus having a motor running at less than its normal load for much of the time, there is the simple expedient of storing some energy in a fly-wheel. This particular application is a 350 kilowatt set. The fly-wheel on that weighs approximately 15,000 pounds and has a peripheral speed of about three miles a minute. The energy stored in that fly-wheel is 300 H.P. for one minute. While fly-wheel motor generator sets have been used to some extent I feel they have not been used as extensively as could be justified.

With the synchronous motor we have all the peaks on the motor, we will not be able to utilize the fly-wheel effect in the same way as it can be used in the induction motor. This particular fly-wheel set is operating at the Hanna Docks at Erie. It has been in operation for a good many years there. The effect of this fly-wheel is that the peaks on the motor average about one-half of the peaks on the D.C. generator to which it is connected. In other words, the peaks are reduced to one-half and the motor has correspondingly reduced rating and operates at nearer its full load.

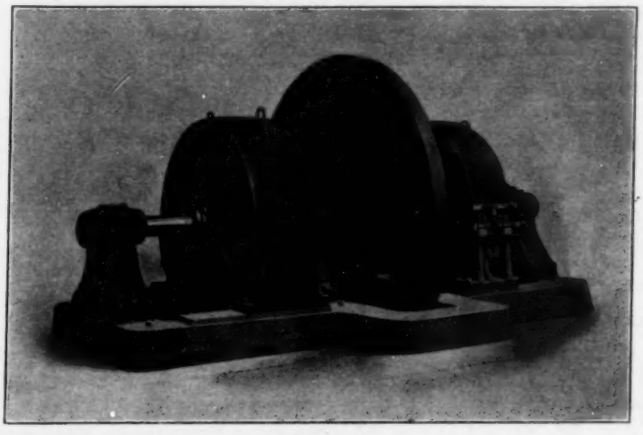


FIG. 14.

Figure No. 15 is a diagram showing a typical case of an induction motor, having wattless current of a relative value of three and energy current of a relative value of four, with the resultant of five and a power factor of four divided by five or eighty per cent.

If we have two such motors we double the horizontal or wattless current and we double the energy current or vertical line, and we double, of course, the inclined line and therefore we have eight divided by ten or 80% power factor. If this happened to be a group of several small motors the effect would be the same.

If, for the second motor instead of installing an induction motor, we have a place where we can place one synchronous motor and it is operated at 100% power factor, we add up our energy line to its full height and we add nothing to the wattless or horizontal current, and we have improved the power factor from 80% to 93½%.

If we over-excite the field of the synchronous motor we will have a horizontal current in the opposite direction which can neutralize the effect of the original horizontal current, and we bring the whole power factor up to 100%. In other words, if this synchronous motor

added to the group of induction motors is operated at 80% leading power factor, it will neutralize the low power factor of the induction motors and the whole system becomes 100% power factor.

Figure No. 16 is a typical stator of a synchronous motor for driving an air compressor.

Figure No. 17 shows the rotor. You will notice that this rotor is split for easy assembling on the compressor.

Figure No. 18 is a view of a high torque synchronous motor. Of course, the great objection, as you will know to the synchronous motor is that it does not have the good starting characteristics of the induction motor. Originally, the synchronous motor had practically no starting power, but the addition of a short circuited winding in the pole faces, which is well shown in this slide, converts the motor into an induction motor at start. It is a rather poor induction motor but, nevertheless, develops considerable starting torque.

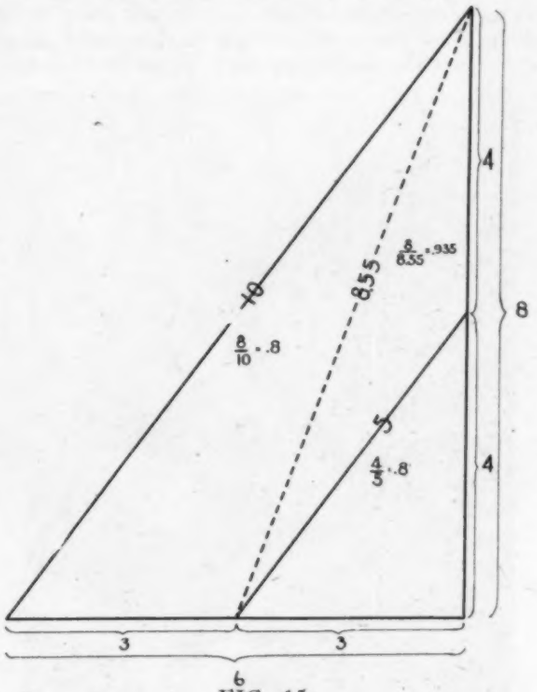


FIG. 15.

In the early attempts the starting torque was not very good, but electrical engineering has advanced considerably, so that today we have good starting and pull-in torques produced in synchronous motors.

Fig. No. 19 is a view of an ordinary synchronous motor with its exciter. One of the complications on all synchronous motors is that in addition to the little complication of having collector rings and brushes you nearly always have a separate exciter for producing direct current for the field excitation, which is the price you have to pay for bringing the power factor up to unity.

Fig. No. 20 shows a better view of the typical starting windings on large synchronous motors.

All synchronous motors even for light starting take quite a large starting current. The amount depends very largely on the speed and many other characteristics, but in general rather excessive amounts are required, compared with the induction motors.

Fig. No. 21 shows a motor generator set consisting of a direct current, 600 volt generator, a synchronous motor, an exciter for the synchronous motor, and a starting motor for the set.

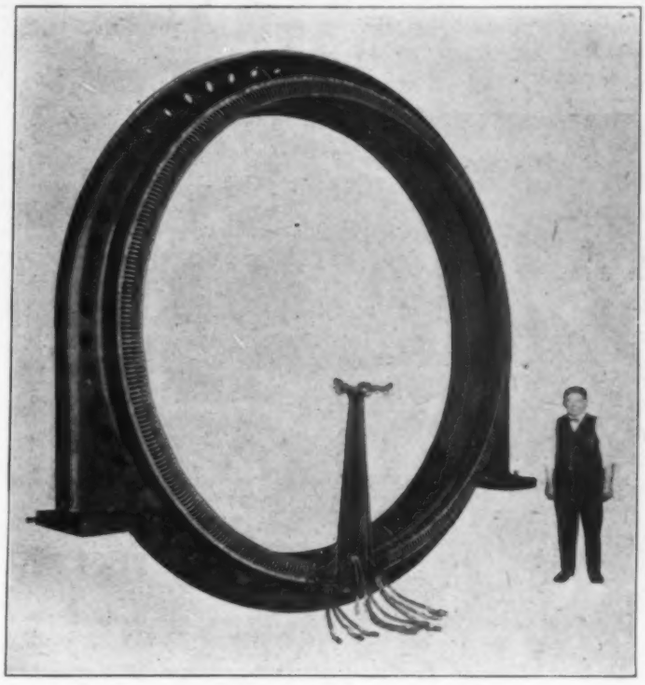


FIG. 16.

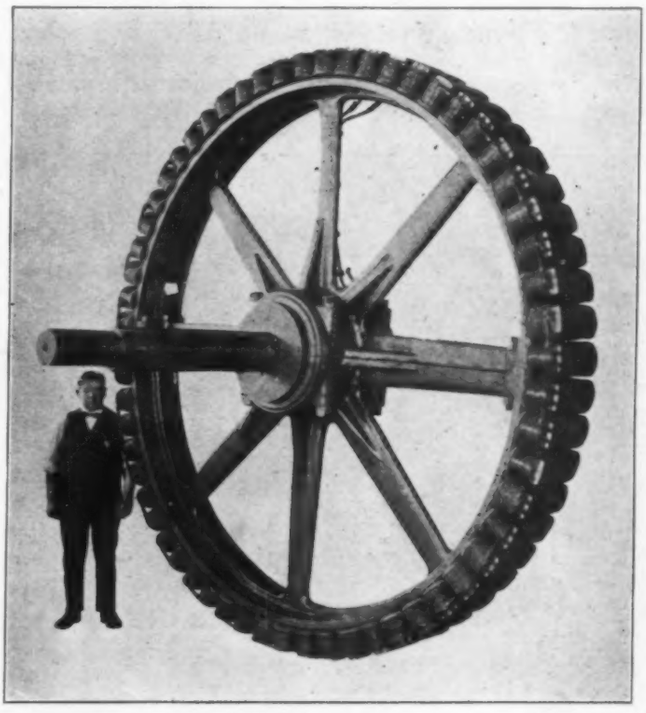


FIG. 17.

The starting motor is an induction motor with two less poles than the synchronous motor, and is connected in series with the synchronous motor.

The power supply is connected to the synchronous motor and induction motor in series. The full line

voltage is applied to the synchronous motor, but the current does not exceed about three-quarters of the full load current of the machine, as it is limited by the induction motor, which, as stated above, is connected in series with the synchronous motor. The high torque produced by the induction motor starts the motor generator set which rapidly accelerates. As the induction motor has less poles than the synchronous

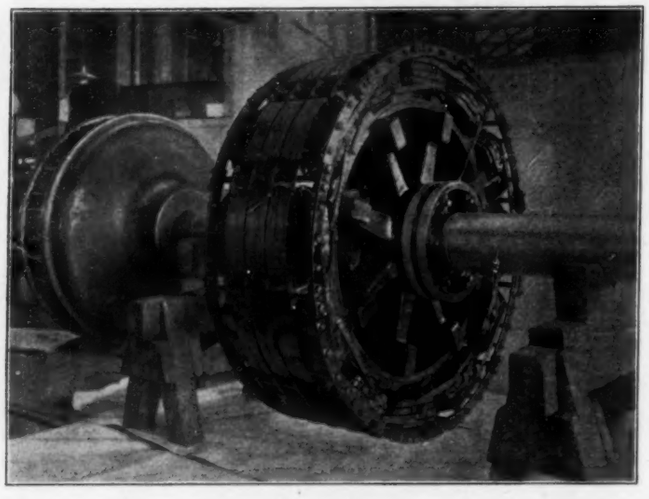


FIG. 18.

motor, the tendency is to assume a speed higher than that of the synchronous motor, but at the instant when the synchronous motor is about to pass through the synchronous speed, it automatically synchronizes and remains in synchronism, the current falling to a value corresponding to the action of the synchronous motor. The starting motor can be left in the circuit continuously if it has sufficient carrying capacity. Otherwise,

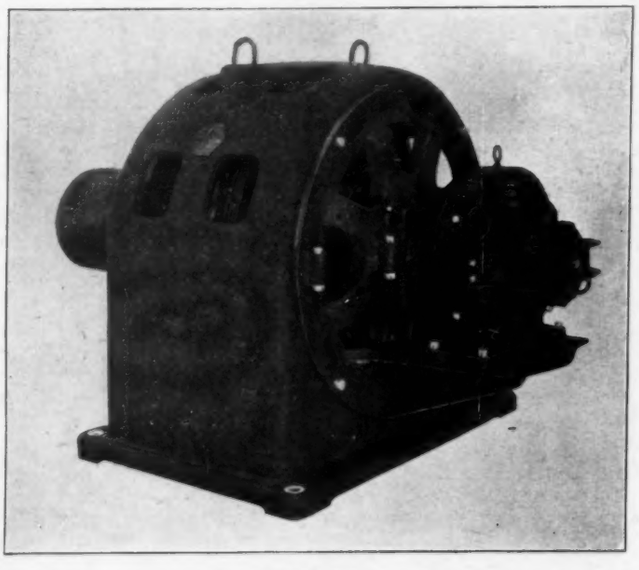


FIG. 19.

it can be cut out of circuit by simply short-circuiting it with a triple pole switch.

This is one of the simplest methods of starting a synchronous motor generator set and one of the most economical on starting current.

Next to the motor generator problem comes the problem of starting fairly heavy loads with a synchronous motor, and one of the earliest methods of doing that was to use a mechanical clutch and to start the synchronous motor up with no load and then close the clutch. It has a great many advantages. It does not draw excessive line current.

A recent development in the application of the clutch principle, and called the "super-synchronous motor," utilizes the clutch principle by so mounting the stator of the motor as to permit it to revolve and come up to full speed while the rotor remains stationary. The stator is then retarded by the application of a brake band, and the rotor, which is connected to the load, starts rotating and gradually comes up to full speed as the stator is brought to rest by the action of the brake band.

The induction motor, while it has a low power factor, is always the same at the same load.

With the synchronous motor you only have a 100% power factor when you have the field current adjusted correctly, and therefore, in order to get the advantage

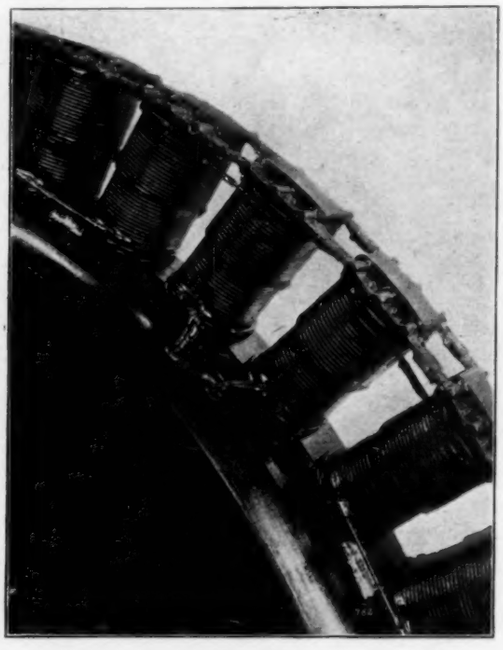


FIG. 20.

of the synchronous motor, you require intelligent operation, this feature to a large extent limits the application of the synchronous motor to plants with adequate electrical engineering supervision.

Fig. No. 22 is a curve showing what happens to the the typical synchronous motor running at about three-quarters load. The excitation is expressed in per cent of unity power factor excitation. Thus, at the selected load, with 100% power factor, we have 100% field current.

Now suppose such a motor is used in a plant that is not under engineering supervision and someone starts the motor in the morning and goes away from it. The exciter begins to warm up and its voltage will drop a little. The field of the synchronous motor will also warm up, and due to the higher resistance of the field of the synchronous motor and lower voltage of the exciter the field excitation will be reduced. It is

not unusual to have the field excitation on typical synchronous motors drop down to about 80% from starting cold until the machine is hot, so if there is no attendant there to readjust the field regulators, the power factor will be reduced as shown in the curve, to 87%, and it will then be as bad as an induction motor. The point I want to bring out is that the benefit of the synchronous motor is only obtained under intelligent supervision of operation.

The world wanted a motor that would have the running characteristics of a synchronous motor and the starting characteristics of an induction motor, and in the first attempts to accomplish this, a slip ring induction motor was used and started in the usual way as an induction motor, and after its full speed as an induction motor was reached, the slip rings were switched over to a direct current supply, joining two of the slip rings together for one pole and using the single slip ring for the other, and thus putting direct current through the rotor winding of a slip ring motor. With this arrangement it was not possible to pull into synchronous against any considerable load, because the rotor circuits were open at switching to D.C. and further the characteristics of the rotor winding of an induction motor were very poorly suited to operation as a synchronous motor.

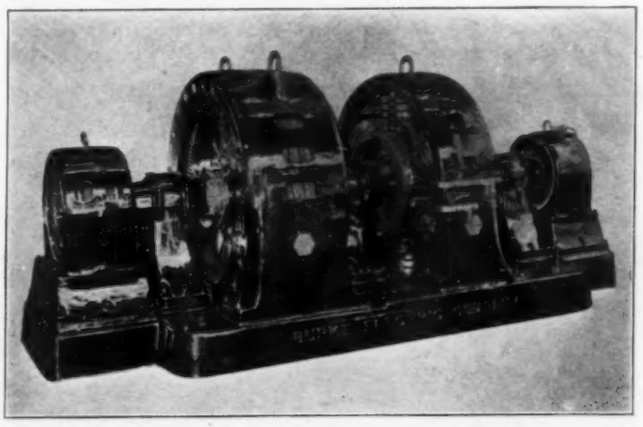


FIG. 21.

Some years ago the Burke Electric Company developed a motor which it called the synchronous induction motor. It has a stator the same as the synchronous motor, and it has quite a special kind of rotor. It is more like the rotor of a direct current generator, except that there is no commutator.

The purpose of this motor is to start as an induction motor having all the good characteristics of the induction motor and to automatically become synchronous without interrupting of the circuits, and to have the power to pull in against full load or overloads.

Fig. No. 23 is a diagram of the connections of a typical Burke Electric Company synchronous induction motor. You will notice the stator is shown diagrammatically, connected to a line supply. This is shown as a two-pole machine for simplicity of the diagram. The rotor is a continuous closed winding like a direct current armature without a commutator, and taps are brought out at four points. Those four points are brought to four collector rings. As shown in the diagram there are two starting rheostats and these are united for one mechanical operation. They are cut out together.

At the start one pair of slip rings, which you will notice connected to opposite points of the rotor, are connected through one of the resistances. The other circuit of the rotor from the other two rings passes

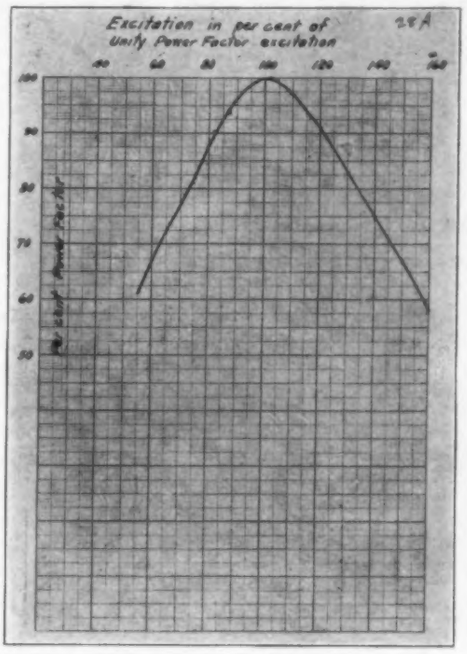
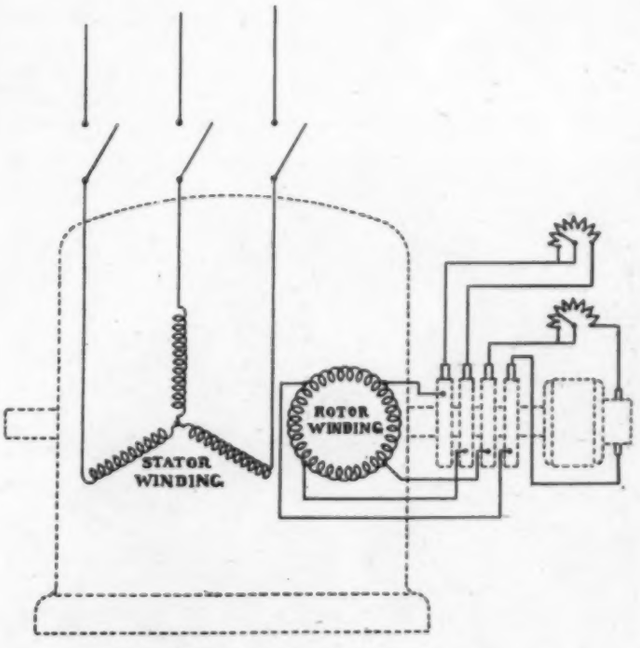


FIG. 22.



SYNCHRONOUS INDUCTION MOTOR DIAGRAM

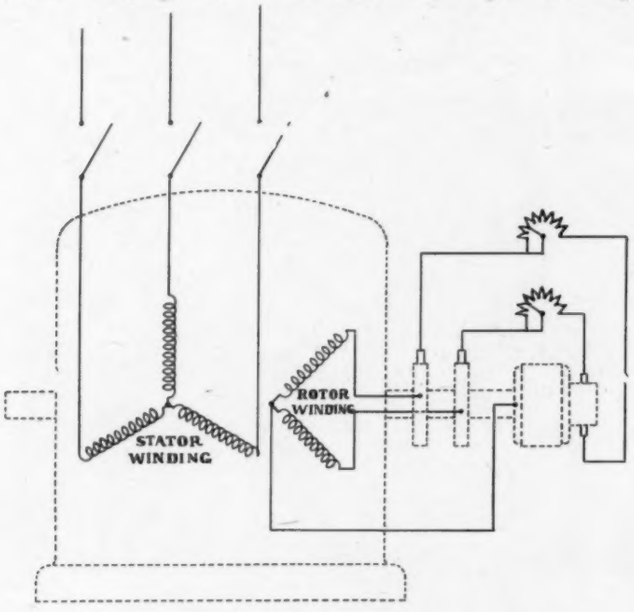
FIG. 23.

through a similar resistance and in series with the armature of the exciter.

In starting, when the main switch is closed, you have a condition of a slip ring, 2-phase rotor, motor, with all the characteristics of the induction motor. When the resistance is all cut out you have a slip

ring induction motor up to full speed, running at, perhaps, three per cent slip.

The slip is necessary to generate the voltage in the rotor winding to produce the flow of current in the rotor winding, and if the motor has 3 per cent slip



SYNCHRONOUS INDUCTION MOTOR DIAGRAM

FIG. 24.

at full load or 4 per cent at full load, the slip has to be just sufficient to generate the necessary voltage to cause the working current to circulate in the rotor.

The function of the exciter is first to generate part of the voltage needed to circulate the current in the

FIG. 25.

rotor, and which, without the aid of the exciter, is generated by the slip of the rotor. As the voltage of the exciter increases, the necessary voltage to be generated by the rotor is correspondingly reduced and the slip is consequently reduced. When the exciter generates all the voltage necessary for circulating the current in the rotor there is no further necessity for generation of voltage in the rotor, and therefore, no longer any necessity for slip and the motor automatically becomes synchronous.

The action of the exciter is automatic after the speed comes up to the full load speed of the induction motor. The motor remains in synchronism and the current exciting the field is a direct current from the exciter. The closed circuit across the rings not connected to the exciter acts as a damping circuit. It is very effective, much more so than could be obtained with ordinary pole face windings, and so the machine continues to operate as a synchronous motor. The power factor is adjustable by the field of the exciter.

Fig. No. 24 is another arrangement of the synchronous induction motor which has some advantages in certain applications. The stator is the same as before. The rotor in this case, instead of being like a direct current rotor, is like a 2-phase induction rotor.

You will notice we have only two slip rings in this case, and in the previous one we had four. This exciter is a three-wire system exciter, from which a

FIG. 26.

point is brought out giving half voltage. If this exciter happens to be 100 volts from brush to brush, it will be 50 volts from each brush to this common point which is, in turn, connected to the common point of the two-phase, three-wire rotor.

At start one circuit of the rotor is through a slip ring, through one resistance, through half of the exciter armature, through this neutral point of the exciter back to the common point, completing the circuit of one phase of the two-phase rotor. The other circuit is similarly from the other ring through the resistance, through the exciter armature and back to that same common point. The cycle of operation is the same as in the previous diagram.

The motor starts as an ordinary, every-day induction motor. When it comes up to speed the exciter boosts the voltage necessary in the rotor, gradually reducing the slip until the machine synchronizes. Motors of this type start as slip-ring induction motors, with all

the good characteristics and torques of the slip-ring induction motors. They pull in at full load or overload. We have built some that will pull in against double full load. They continue operating as synchronous motors. If there is a condition of excessive overload, they are pulled out of step and they become induction motors. When the excessive load is removed they return to operation as synchronous motors. The point of break-down where the motor will pull out from being a synchronous motor to being an induction motor is determined by the field excitation, so that a machine of this kind can have a flywheel which will not give up any energy until the point when the breakdown occurs, and the motor then becomes an induction motor, assumes a slip of perhaps 4 per cent and the flywheel energy is given up suddenly at that time.

Fig. No. 25 is a photograph of a 350 H.P. synchronous induction motor.

Fig. No. 26 is a photograph of a 1000 H.P. synchronous induction motor direct connected to a pump. You will notice the slip rings within the bracket and the exciter carried on the bracket. This motor is operating a pump which is always started with the valve

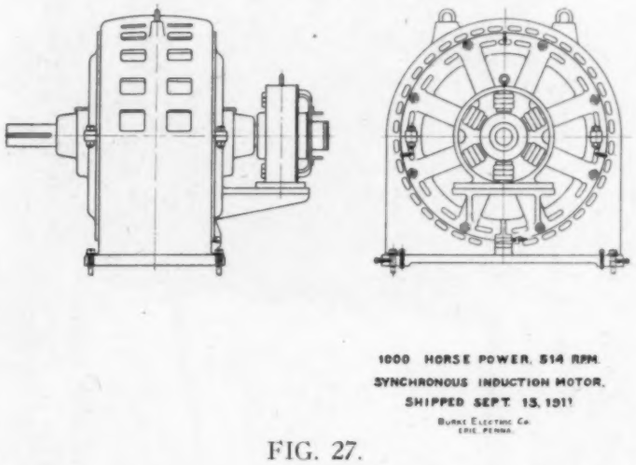


FIG. 27.

wide open, therefore it has to pull in against the full load. There is no throttling of the water, and the load that it pulls in against is the full load that it has after it synchronizes.

Fig. No. 27 shows the design of this machine. This motor is 1000 H.P. at 80% leading power factor. Its starting current is only 60% of full load amperes. It pulls in against full load torque without exceeding its full load current.

Fig. No. 28 is a cross section of the 1000 H.P. motor just referred to. You will notice the stator is the typical induction motor stator or synchronous motor stator. The rotor is like the rotor of the direct current motor. There are four taps brought out from four points as shown in the diagram to these four rings.

Fig. No. 28 is the efficiency of that motor. The guarantee is the lower curve and the actual test made after its installation is the upper curve. You will notice at the full load of 100% the efficiency there is 94½. Today with the improvement in electrical steel, we could probably do better, but 94.5% is excellent efficiency for any motor.

Fig. No. 29 is a synchronous induction motor connected to an air compressor, which starts without any unloading devices on the cylinders. It pulls into synchronism in the manner I have described. It is a

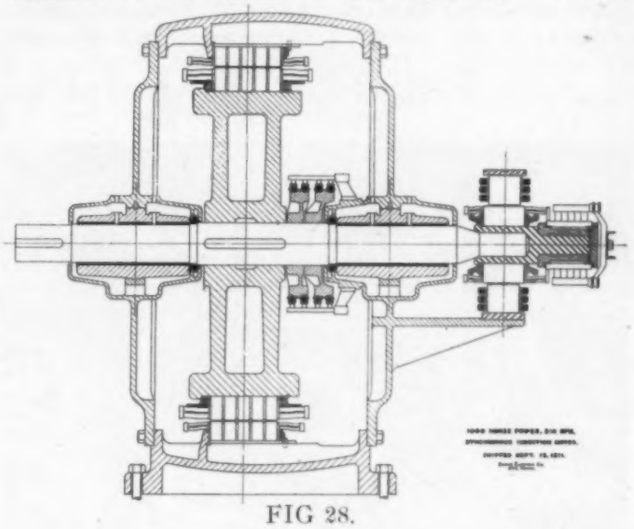


FIG 28.

large, low-speed compressor. In this case the exciter is a motor generator set.

Fig. No. 30 is the starting panel for a large synchronous induction motor. It has the various instruments on it for all the usual purposes and also recording instruments.

The process of starting is to close switch No. 1 The motor starts up and when the amperes have dropped down to what the operator considers is low enough to give it another step of current, the next

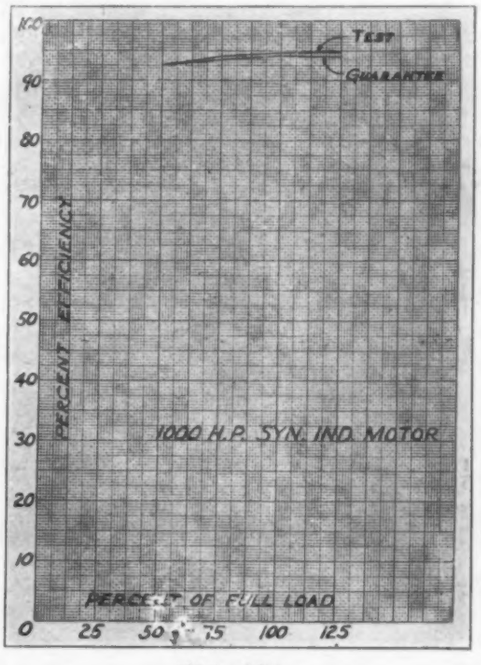


FIG. 28A.

one is closed, and so on the switches are closed in regular order and the motor comes into synchronism, taking care of its load. That is all that there is to do, just the closing of the switches in succession.

Fig. No. 31 is a panel of about 500 H.P. synchronous induction motor. This main line is closed and then these other switches are closed in regular order, just in the same way as you saw on the previous machine. There is no need of watching out for anything to do, just put in the switches in succession.

What I have tried to do is to cover the various types of motors and to show you all the choices that

FIG. 29.

we have to work from for various applications. It is my opinion that small motors should be induction motors, because a synchronous motor has to have a certain amount of service and attention; it has to have direct current excitation and usually a direct connected exciter nearby for convenience, or built into it. The saving in bringing up the power factor of small motors

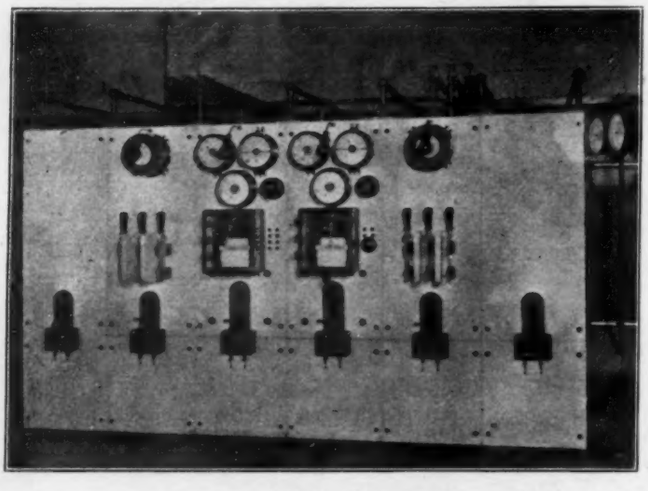


FIG. 30.

by the substitution of synchronous motors is offset by the service they require.

By larger motors I mean when we get above 50 H.P. or 100 H.P., depending upon the installation. Where the starting characteristics of the load will permit, you should have synchronous motors. That is usually in a plant of some magnitude where all the small motors can be induction motors and a few large synchronous motors operating at leading power factors to bring the average of the whole plant up to somewhere near 100 per cent power factor.

All motor generators should, of course, have synchronous motors on them. I mean the plain, every day synchronous motor, because the starting characteristics of the motor generator set do not require any excessive starting torques. When, however, the starting current is limited so that the starting of the synchronous motor on the motor generator set is a heavy draw on the line, then the type of motor generator set with induction motor starter, I think, should be used. It has the advantage of keeping down the starting current and also makes for simplification in starting. Wherever the starting characteristics of the load can be taken care of by the ordinary synchronous

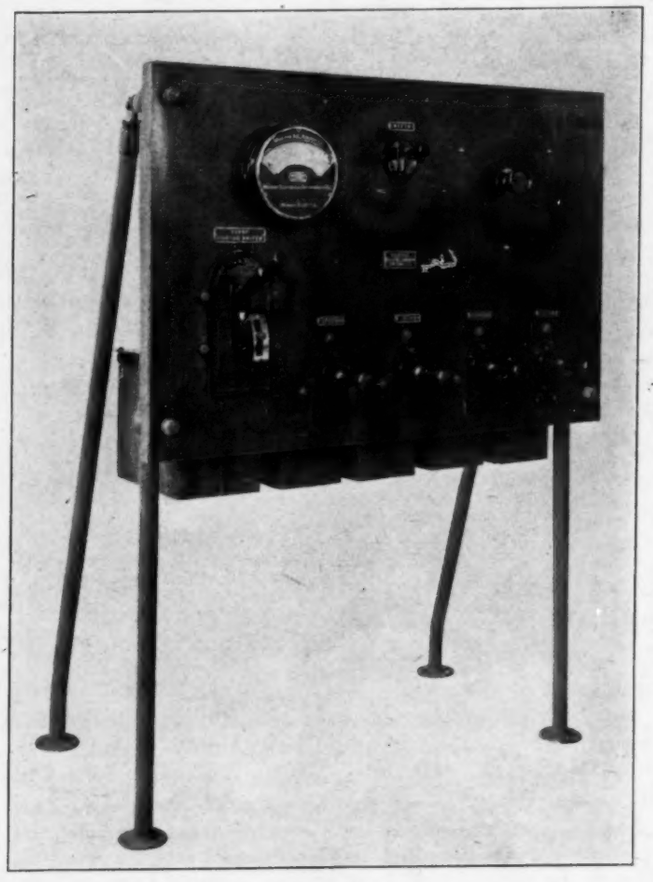


FIG. 31.

motor and where consumption of current is of no great importance in starting, that field can be taken care of by the synchronous motor. Where, however, greater economy or fair economy in starting current is necessary or advantageous and high starting torques are necessary we have the intermediate field of the clutch motor, the super-synchronous motor which is a type of clutch motor or the synchronous-induction motor.

The synchronous-induction motor has one advantage over all other types of synchronous motors, namely, that it operates as an induction motor. If anything goes wrong with the excitation you can continue oper-

ating it as an induction motor and you usually have a very good induction motor.

The curves which I showed of the efficiencies of that 1,000 horsepower motor were operating with a leading power factor of 80 per cent. That motor had that capacity for 80 per cent leading power factor. That same motor operating as an induction motor at its rated load has a power factor of nearly 90 per cent. So that you are not shut down or handicapped very much if there should be anything go wrong with the exciter, and we all know that exciters have commutators and notwithstanding what we manufacturers say about them, they do require attention. The best of them give trouble occasionally and have to be trued up.

One of them which has been taken advantage of is that occasionally a motor requires speed variation. Now with the synchronous induction motor while operating as an induction motor, it can have speed control the same as a slip ring motor and yet, at other times, when you do not need speed control, you are operating as a synchronous motor.

Also, there are applications where there is an advantage in having a motor which can operate as an induction motor, as well as operate as a synchronous motor and they are usually very great advantages. Many such will occur to you engineers who are specializing on motor applications.

DISCUSSION

D. W. Dean*: I certainly enjoyed Mr. Burke's talk this evening, and if the other listeners have enjoyed it as much, Mr. Burke should feel well repaid for his time.

Mr. Burke mentioned one point that we sometimes lose sight of, that is that all these types of machines require excitation. We usually think of the D.C. machine and the synchronous motor as requiring excitation. The induction motor does, also. It gets its excitation from the A.C. line and the exciting current is the cause of the poor power factor.

As Mr. Burke mentions, the reasons why we are interested in improving the power factor is the added capital investment that we have to make to take care of the wattless A.C. exciting current that passes through the generating equipment, transformers, etc., and also the effect on line regulation.

There is one point we sometimes lose sight of when we get our synchronous apparatus all at the incoming line or all at the power station. That will help us at that immediate point. That does not help us on our line conditions any at all, because we still have our line losses. Therefore, if we are going to get the real benefit of corrective equipment we should have it well distributed throughout the plant. If we could put our corrective equipment adjacent to the machine which requires the lagging current for excitation that would be the ideal position. Then we don't have to take our exciting current through the transmission line, etc.

*Elec. Engr. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

There is one means of doing this now which hasn't been given so much consideration in the past, because it was not reliable, and that is what is known as static condensers. I believe since static condensers have now been developed where they are as reliable as transformers and have an efficiency of 99½ per cent, an engineering analysis will often show that they may be the most economical means of securing the improved power factor conditions.

Fortunately, the whole power factor question is one that can readily be analyzed in an engineering manner. Recently in the Canton district, I know of one concern that made a very complete power factor analysis. They did this primarily with the thought of eliminating the penalty referred to by Mr. Burke. After the analysis was made they found out that by putting in a 4,000 K.V.A. synchronous condenser the power factor would be improved to such a point that the discount on their power bills would pay for the equipment in a short time.

Another interesting point in connection with a power factor study mentioned by one of the members of the A.I.&S.E.E. in a talk on this subject was that the power factor study actually showed where he could revamp over-motored installations, put on smaller motors, and the motor capacity which he could remove under these circumstances more than paid for the cost of his investigation. That is, he had this excess motor capacity available for other work.

In connection with steel mills the main applications for synchronous motors are the synchronous motor generator, compressors and pumps.

There has been some agitation for the application of synchronous motors to main roll drives. We usually think of the starting conditions being the chief limitation on synchronous motor applications and they are, as Mr. Burke pointed out, but he pointed out one other thing which might be emphasized for main roll drives, and that is the inability to smooth out peak loads by the use of flywheels in connection with synchronous motors.

As an illustration, I know of just an ordinary train of six stands in a row with a motor at one end which was analyzed recently with the idea of using a synchronous motor if starting conditions would permit. You who are familiar with this type of mill know that there may be as high as three or four billets going through at one time. The billet may be entering at the first stand, about halfway through the mill a billet will be partway finished, and a bar may be coming from the finishing rolls. In these cases where you have the passes doubling up on each other you will realize that you are going to get some sharp and high peaks. In this particular case the analysis showed that by putting on a flywheel of about 6,000 horse-power seconds, which would be about one-third the capacity of the flywheel referred to by Mr. Burke, which had 18,000 horse-power seconds, these peaks could be smoothed out so that a 400 horse-power wound rotor induction motor could be used. In order to take care of these peaks with the synchronous motor, a 750 H.P. motor would have been required.

Another point mentioned by Mr. Burke was the use of magnetic clutches in connection with synchronous motors. They have been used very largely in rub-

ber mills, but not so much in steel mills. There is one point in the use of these clutches which needs to be watched with care if they are to be applied where you get the severe starting conditions that you do in some steel mill loads.

For example, with the magnetic clutch you have friction surfaces. Now on the one side of your magnetic clutch, the mill side, you are going to have a low speed to start up with; that is, you are going to start at zero speed and increase gradually to the friction load speed. Assume that during that you have got just friction load torque which will be a constant torque proposition in accelerating. Then, as you are rotating here at your friction surfaces, you have constant torque on both sides of your friction surface. On this side you are increasing your speed from zero up to friction load or increasing your horse-power output from your clutch from zero up to the friction load, and on the other side of your friction clutch you have still the constant torque applied. In other words, when the input side of the clutch has a constant speed of your synchronous motor, so you have your output going from zero to friction load, but you have more or less a constant input here which is practically equivalent to friction load all during the starting period.

That energy which you put in there which you don't get out on your load side must be dissipated as heat. Now if you get into our severe starting conditions as we do in the steel mill, unless we take care to have the magnetic clutch which will have a great thermo-capacity and be able to dissipate this heat, we may get into trouble with the warping of the surfaces and abnormal wear of the friction linings.

I don't want that to be taken as a knock against the magnetic clutch in any sense of the word, because the magnetic clutch is a very reliable piece of apparatus and very suitable to certain conditions. For any sort of an application one can depend in full faith on the manufacturer's recommendations, because they are aware that thermo-capacity is in there.

Another point with regard to the severe starting conditions that might be met in steel mill service is that the synchronous motor, as Mr. Burke pointed out, will take a very high KVA input at the instant of starting. This high KVA must go through the auto-transformer. If we consider a main roll drive where we are going to have very severe starting conditions, we find it is sometimes necessary on Monday morning, especially in the winter, when we have frozen conditions at the bearings, to rock the motor back and forth to overcome this abnormal static friction. Now unless very special auto-transformers are used in cases of this kind, assuming that the synchronous motor otherwise would be suitable, there would soon be plenty of auto-transformer trouble.

I don't want these remarks taken as a knock against the synchronous motor in any sense of the word. We all know it has its field. It is doing good work in the steel mills. But if one is going to try to make a general application of the synchronous motor in the steel industry, caution will have to be used to prevent misapplications.

I noticed that the field coils in some of the D.C. exciters shown by Mr. Burke were in pancake sections. I wonder if the sections were connected in series if there was some special electrical connection? One view illustrated a means for obtaining an adjustable air gap. I assume the air gap is adjusted at the bottom and at the top and the total air gap is not changed.

H. B. Dates*: I am not a steel man and therefore cannot speak for the synchronous motor from the standpoint of its application to steel mill use.

I have had some cases come to my attention, however, wherein the advantages of replacing other motors with synchronous motors or adding synchronous motors in preference to other types has worked out particularly well from the standpoint of the over-all economy involved.

That is, the use of synchronous motors in these cases by improving the power factor, has obviated the necessity of increasing transformer capacity and the sizes of feeders and conductors in the distribution sytem, resulting in savings sufficient to pay for the synchronous motor over a reasonably short period of time.

H. L. Wallau†: I don't know that there is much that I can add. I might cite an illustration. A great many years back we had a certain local power circuit out of one of our substations which was totally loaded in KVA and there was an industrial load to be had in that territory for which we were able to induce the customer to install a synchronous motor generator set. We then carried 50 per cent more KW on that same circuit with about 75 per cent of the previous, so that it was a distinct advantage from our point of view to have had this synchronous motor application.

E. W. P. Smith‡: While we are not manufacturers of synchronous motors, we had an experience similar to what has been outlined here this evening, that is, running at low power value in our plant. We had exactly the same situation as mentioned by one of the central stations. Our lines were loaded very heavily. We had several test sets which were running idle for considerable length of time, and the load, of course, varied.

We put in synchronous motors, increased the power factor, with the result that in other parts of the shop we could take off these same lines more power and drive other machine tools with a consequent increase in production. In other words, a slight change in our equipment on our test floor permitted us to increase our manufacturing output. I think that is an angle which has not been brought out with sufficient emphasis, other than the fact that you can get more power on the same lines when you increase the power factor.

P. Justus§: The only thing I can add is that I have enjoyed Mr. Burke's talk very much. I happen to be wrestling with a problem along those lines at the present time. It is a case of a plant having a connected load of some 240-odd horsepower and actually using about sixty. The consequence is that the bill is practically double. The question before us at the present time is whether static or synchronous induction motors would be the best remedy to correct that poor power factor.

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*Professor, Case School of Applied Science, Cleveland, Ohio.

†Electrical Engineer, Cleveland Electric Illuminating Co.

‡Chief Engineer, Lincoln Electric Company.

§Chief Electrician, Chandler Motors.

James F. Burke: (answering Mr. Dean's questions): The vertical sections shown in the photographs of the field coils are simply in line with our standard practice of dividing all of our field coils into several sections for the purpose of greater safety against breakdowns and improved ventilation.

Answering the question with regard to the adjustment of the air gap, the adjustment is simply to adjust for the wear of the bearings. The wedges at the bottom of the bracket raise the bracket and the bearing with it, and there being suitable adjusting screws in the upper section of the motor to co-operate with the adjusting wedges.

Prof. Dates has referred to the fact that with synchronous motors decreased transformer capacity is possible. This is very true. Not only are the transformers relieved of some load by improving the power factor, but their regulation is very much improved. The regulation of a transformer being usually three or four times as much in drop of voltage on the low-power factors than on the power factors of 100 per cent.

Mr. MacCutcheon brough up the point that the synchronous motors on shipboard appeared to him as being direct current motors. They have no commutators.

As to his complimentary remarks about the gyroscope, all the pioneer gyroscope work has been done by Dr. Sperry, and all that I have done is to co-operate with him from the standpoint of building suitable electric motors for the purpose. Of course, they have been quite special motors and there has been much interesting engineering work in connection with them.

Answering Mr. MacCutcheon's question as to the cost of the starting motor, it costs less than the usual starting apparatus for a synchronous motor, consisting of a compensator and suitable switches. The characteristics of the motor are that it is a plain, short-circuit squirrel cage motor of high starting torque. Usually it is rated on a short-time duty service because by a simple switch joining three points together, it can be cut out of service. It, therefore, does not have to have the capacity of carrying the line current continuously. If, however, certain conditions of operation, such as automatic substation work, would make it desirable to leave the starting motor in all the time, a somewhat larger motor would be necessary.

He also brought up the point of definite poles compared with the distributed poles. Most of the turbo-alternators today have in their rotors practically the distributed pole magnetic effect; in other words, they do not have definite salient poles, and, as we know, the distributed pole is satisfactory in turbo-alternators, and perhaps more satisfactory than salient poles. It is equally so for synchronous motors. Our own experience has been that there is very little difference in the cost of building a machine between that of salient poles and distributed poles. With the synchronous-induction motor the distributed pole is necessary. It is the same kind of a machine as an induction motor, and the rotor is an induction motor rotor.

Mr. Smith has brought up the point of increased output by the use of synchronous motors. That is undoubtedly true. In many localities on account of increased power demand, there is a question of whether increased generating equipment and distribution copper shall be installed or synchronous motors. Perhaps I am a little prejudiced, but I generally recommend the synchronous motors.

Mr. Justus asked whether static condensers or any other kind of condenser could be added for improving the power factor. The static condenser, as pointed out by Mr. Dean, has a very high efficiency, but it has also a very high cost, and in the comparisons which I have been able to make, the interest on the investment of the static condenser plus the depreciation which, whether it occurs or not, the accountants of plants charge against all equipment, is about equal to the cost of operating a synchronous motor even without any real load on the motor, using a synchronous motor purely for the purpose of power factor correction. So that in any case, where you can use part of the capacity of a synchronous motor for actual work, you get practically that much gain in capacity of your plant.

There is one point of great difference related to the number of hours a day a plant operates. If a plant operates 24 hours a day the lower efficiency of the synchronous motor, when used alone, without any work, makes the comparison more favorable to the static condenser, but in all cases, where a synchronous motor can be used for doing some real work, as well as correcting the power factor of induction motors, all my comparisons have shown that the synchronous motor has advantages over the static condenser. There is one point, however, which favors the static condenser and that is, that it does not have an exciter to be looked after, and in plants where there is no service, no intelligent electrical care of machinery, perhaps the synchronous motor with its exciter, would not be as favorable as using the static condenser.

Answering the question as to the higher speed of the induction motors resulting in a higher power factor and higher efficiency, as a general proposition, the efficiency and power factor of all induction motors increases with the amount of power per pole.

Now, if you take a 25 horsepower 60-cycle induction motor at 3600 rev., having 2 poles, you will have 12½ horsepower per pole. Of course, that is a very high-speed motor. If you add 2 more poles you will have 6¼ horsepower per pole, and it will then have a speed of 1800 rev. If you take a 10-pole motor it will have a speed of 720 and 2½ horsepower per pole. A motor of 2½ horsepower per pole will have a much lower efficiency and power factor than a motor having 6¼ horsepower per pole. The real comparison of efficiencies and power factors of various motors is related to the horsepower per pole.

Looking at it another way, a 25 horsepower, 4-pole, 1800-revolution motor would have about the same power factor and efficiency as a 50-horsepower, 8-pole, 900-revolution motor, because in those two cases both would have the same horsepower per pole.

The Differential Pressure Steam Generating System*

By LESTER P. BARLOW*

MR. CHAIRMAN and Gentlemen of the Society: About a year ago when I received a communication requesting me that I address this group, I turned it down One reason was I was not sure I'd be in the city (I am out of town a great deal), and the other reason was this: I am not a technical graduate, and I am just a little bit "skiddish" about telling a group of technical engineers anything. But I find I have my place in the mechanical world, and have successfully mastered several problems in the inventing field, and have a great number of patents. My success with things which were presumed unnecessary or impossible gave me the confidence necessary to continue that class of work, and I really feel that I have the advantage of the average technical man in this way; I don't know any better than to try something that hadn't ought to be tried, presumably. If I get licked at it, well, I don't say anything. If I win out—well, he is a pretty wise bird after all!

I don't want to be classed exactly as an inventor; it has its drawbacks. I was testifying before the Department of Justice, and Judge Hughes, now Secretary of State, was doing the questioning, and he started off one day on my work. He said: "Are you an inventor?"

I said, "Not quite."

He said, "Why not?"

"I am an engineer."

"You invented such and such a thing, didn't you?"

"Yes, I did."

"Isn't that inventing?"

"Well, I am not quite in that class. I am an engineer."

"What is the difference?"

"An inventor works on things way ahead of his time. He generally does most of that work either in the cellar or the attic, and he starves to death. Fifty years afterwards he is honored as a man ahead of his time, while the engineer works on the problems of the day, solves them successfully, and gets paid for his work."

Down in New York, being an inventor, as I say, has its drawbacks. I was testifying down there a while ago in a law suit. The attorney on the other side was questioning me, and he started out and jumped on that point again. "You are an inventor by profession?" he said.

"Well, perhaps."

"I want to call the attention of the Court to the fact that this man is an inventor"—just politely saying, "Your Honor, here is a nut!"

On this differential pressure steam system, I am not coming here with any prepared papers, I am going to speak extemporaneously. This work is a work that has been, to some extent, successful, but it is in the development stage. It is not yet in commercial production. There are still several things that must be mastered, but it does give us an outlet around several very difficult steam problems.

This system has been developed to take care especially of the places where we want great power from small places, and from mobile units like the locomotive or the automotive field. It is not developed to run in competition to the stationary steam plant such as our central power stations. It is to be used where we need circulation and haven't the head room to build steam generators several stories high.

Under this system we can get at present for railroad service, a circulation of the water that is much greater through the generator than through the present stationary system. It is possible to get under the hood of an automobile 75 to 100 horse power output. The fuel question has forced the generation of power into new fields, and we find the Deisel engine encroaching upon the steam field more and more.

There is going to be considerable of a contest between these two power systems, I think, from now on. The newest field for the Deisel engine to enter is the locomotive field. We now have a Deisel switch engine in New York City which has now been transferred to other work, but the success of that Deisel locomotive driving a dynamo generator, which in turn drives the trucks, has been so marked that the New York Central has ordered the designs for six similar engines, at least I was told so by one of the officials of the New York Central. The reason for that combination locomotive is this—it does away with the time of steaming up and keeping under steam a locomotive many hours while it is standing waiting for orders. It also eliminates the trouble of boiler washing, and furthermore, it gives a very high starting torque, because they can shunt the fields, the motors, and get the train under way, and then they can go back to the first position of the motors and travel at a higher speed.

There is a possibility and a probability that in the next few years they will be driving either Deisel electro locomotives direct through from New York City to Chicago, or high pressure steam driven generating sets driving electric trucks. The Cleveland terminal, of course, will be an electric terminal. We have the New York terminal, then the Cleveland terminal, and in 1927 some of the roads are under contract with the City of Chicago to electrify, and in the coming years, probably by 1935, Chicago will have her lines under electrification.

That complicates things unless the lines having these high-speed trains through to New York City and Chicago are electrified, otherwise it will necessitate at least four changes of locomotives between Chicago and New York. The Deisel engine, however, in that work, will be perhaps limited by this fact—fuel. Unless we can extract some kind of liquid fuel from coal, the Deisel engine will be limited to the oil fuel that we take from the wells. We can hardly conceive of the

*Engr. Keith Theatre Bldg., Cleveland, Ohio.

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American railroads being operated by oil to any great extent remote from the oil fields.

The two fuels that we have to depend upon today as mobile independent power fuels are oil or coal. We do not consider the electric locomotive as independent. It must remain in contact with its source of power, although it is going to give the steam locomotive a heavy run in the contest where we have water power to give the white coal.

But apart from the water power, and in the sections where we must transport fuel, the contest will be between the internal combustion engine and the high pressure steam system. The internal combustion engine, like the steam engine, has its inherent drawbacks. It will be a very difficult matter to keep the bearings of a high-power Deisel engine suitable for handling large trains in alignment, for instance. The base of that engine must be extremely rigid to take the shock of the road and support the rigid bearings.

Even on a steamship, take the long shaft going down through the shaft tunnel; I suppose there are a number of you who have passed down the shaft tunnels of some of the larger ships back a few years, especially in the Navy, and noticed those shafts were of great diameter. They had to be that way in order to take care of the weave of the hull, and the same conditions hold true on a locomotive of the Deisel type. They have found that to be true. That is a trouble we would not have in the steam engine.

The Barlow differential pressure system can be utilized wherever we have the necessity of getting great power from a very compact space, and what primarily developed in the beginning for automobile purposes, and I will give you some inkling of what the system contemplates.

I have no slides, so I have asked to have this black board available so I might explain the system. In the differential pressure system, which is under contest at the present time at the Patent Office, the War Department requested this patent be put through especially for military purposes, and I have a contract with the War Department whereby they have the exclusive rights for military use, for gun tractors, etc. It makes an excellent tractor power plant, makes an excellent plant for machine purposes, and there has been some study on it with the Navy Department in regard to submarines.

There are several nations at this time working on steam-driven submarines. These submarines must have speed. They think the next war may be fought in deep water, and they can't go to the bottom, and they must have steering control so they must operate at least three knots an hour at least 34 hours under water without fire. The steam possibility there is not as disadvantageous as it seems. The one drawback to the whole thing is not temperature or the maintenance of temperature, but a container to carry the water under a high pressure, which means, of course, high temperature. The containers that have so far been worked on would be so heavy the boat couldn't carry them, but it would be an easy matter to hold the temperature over a period of two or three days sufficient to operate a submarine. Also, the boat must travel under water for one hour at full speed to meet the specifications.

The French claim they have that problem mastered. The American Government does not know yet how the French handle it, but this system has been considered.

There are two sides to the differential pressure system. The containers, or what we call accumulators, are large tubes, tubular to stand the pressure. These containers are not in the firing zone, although we have had it under operation by having containers in the firing zone, but we realize the space these containers take is very valuable space for heating, and we can get considerable more results and efficiency by utilizing that space for the heating element.

In the firing zone we have the coils; we can have a series of coils, or multiple coils. I will show one in order to give the illustration of circulation.

The patent drawing of this is very simple, far more simple than the actual set-up, but it is simple merely to show the system. The records of patents do not show any prior article, and we are asking basic patents on it, although since the patent has been allowed, in fact it has been allowed twice, there has been a leak at the Patent Office, and we are now having quite a battle on the patent of this device. I believe that those who can control this patent will ultimately control the high pressure systems.

We operate first as a piston pump circulator—the device is really rotary. It is an automatic mechanical force circulation which is in direct proportion to temperature. It is absolutely impossible to burn up one of these systems, there is no scale, and the limit of steam is the limit of fire. It is not a limit of circulation or a limit of surface. The steaming capacity of this generator depends entirely upon the amount of fire. You can throw an oxygen charge into the furnace and feed it as fast as you wish; there is no limit to the life of the generator as far as temperature is concerned.

We have here a cylinder one-third the area of the upper cylinders. These two cylinders are connected by a tube; the smaller cylinder is connected at the bottom of the accumulators. There may be a number of those accumulators; also a number of firing zones. You may have as many firing zones as you wish, all in communication with accumulators. For instance, on board ship, a section of the ship may be set apart for these accumulators. We can have one or two of the heating sections maintain the pressure, and inside of three minutes from the ringing of the bell in the fire room from the bridge, you will have full steaming capacity of the largest ship. When your fire is thrown on, your water enters here, and all heat, in this system is transferred above the water level instead of below. That does away with priming and foaming. At all times under normal operation the heat delivered to the water is delivered above the water level instead of below the water level. That is an absolute reverse of anything you have known heretofore in steaming. It does away with priming, and meets one of the problems of high pressure steam, which means high temperature and quick delivery.

As the fire is thrown on, there is no possible way for the expansion within the heating section to pass to the accumulators without passing through across one or the other line. The piston in the upper cylinder is three times the area of the piston in the lower cylinder; just ordinary feed water pumps dimensions so that the piston at the top will overcome the piston in the lower cylinder, due to the greater area of the piston, and the expansion of the steam will pass over above the water level; but in moving that piston with expansion, which is three times the volume of the water incoming to the

coil, we are moving this piston and taking the water from the bottom of the accumulators to the bottom of the coil. The greater the temperature, the faster the piston moves, and the greater the water driven into the coil. That is the basis of the differential pressure system.

Now, then, the first operation of this was back in 1917 during the war. I built that one in New Haven, Connecticut, at the Liberty Aviation Field, of which I was in charge, and where we developed most of the high explosive aeronautic bombs during the war.

I put the first system into an automobile, and had a great deal of difficulty controlling the speed of the pistons. If I'd throw the throttle open suddenly the circulator would almost jump out of the car. Another thing was, the single cylinder would not pass the water. Since then we have built duplex types, and from that to the rotary. The first rotary was built in Detroit in 1921 and in that system we have the rotary head here and a rotary head there. The present type is the very successful rotary heads, known as the Northern Fire Engine equipment. Every feed pump on all the major battle ships of this country today feeding the boilers at 350 pounds pressure use Northern rotary pumps; practically all the pumps on main line ships are of the rotary type. That type of pump has a very peculiar head, but it makes an excellent motor as well as an excellent pump. We put one head three times the area of the water forcing head on one end, and the water forcing head on the other.

The reason we have these tubular connections, for instance, on the piston pump, we have the piston rod passing through that tube and bushings at each end. As soon as this tube fills up around the piston with condensed steam or water, you will find the pressure is under this piston shoving it up to the accumlator itself, also trying to leak out around the rod. The same pressure acting against this piston coming up as soon as this chamber has become filled with water makes it impossible to have a leak in either direction. The same thing works out in the rotation or the rotary element. I will give you an illustration of the rotary heads that we use in this system.

That is the shape of the rotary in the Northern pump, which we are using in this differential pressure system. There are two of each. The other one would be here, etc. The gap would be like this, the pressure coming in at this point drives this wing, just like the ordinary gear type of pump, except we have a greater capacity over out at the top, and drives the other one in the other direction. The heads are of the same diameter, but of greater length, one just three times the area of the other.

With this system we can drive the water through very small tubes, for instance, a tube in a job, we will say, of 1,000, 2,000 or 3,000 horse power, the tube would not be larger than one inch in diameter, the thickness of the tube not more than one-sixteenth, and at 1,000 pounds pressure a factor of 6 or 7.

There is absolutely no danger from explosion under this kind of a system. The tube, instead of being 8 or 10 feet long or 20 feet long, of larger diameter, would be a 1 inch tube from 60 to 70 feet in length. That would cut down tube ends and cut down tube sheets, and cut out great drums. On the United States Navy torpedo boats, the steam heads, at the tops of the tubes are 4 inches in wall thickness, forged to this thickness. That means quite a lot of metal to keep hot. In this system we enter our accumulators, with one tube, thereby using a very thin wall section and light weight and low cost. You can have as many tubes as you wish, have them in multiple, and drive the water through these tubes at a very high rate.

There is one thing that is very essential under this system, and that is, that all tubes be of the same length, so that the resistance is the same and there will be no short circuit of the water passing through part of the tubes and the other becoming hot and starving.

At this point we put in what we call a precipitator. That precipitator may be horizontal or vertical. It has a core of cast iron. Around this core is a light metal jacket, and the whole thing is carried within a chamber, at the bottom of which is the blow-off value. That is a spiral section, and there is the spiral the water courses around, giving us great centrifugal force. The water from the accumulator feeds into the top of that and spirals around the core, inside, however, the light steel jacket at this point. At the top where the water enters, the feed water enters also.

The water in this chamber at 600 pounds pressure is 486 degrees Fahrenheit; 265 degrees is sufficient to cause complete precipitation of all silicate, etc., that causes scale. We have even gone so far with this with the American Locomotive Company as to extract the gasses, and I believe this system will develop in time to an excellent dehydrator. But by passing the feed water into this line of circulation, one part, to say, five parts of this water circulation, we instantly bring the water up, the feed water, way beyond precipitation temperatures, or way beyond 300 degrees Fahrenheit. We cause precipitation to instantly take place in this spiral, and looking at that as a section, the chambers surrounding that—as it comes around hugging the surface, it slips out into the dead water and lodges in the bottom, and we blow it off. This application of precipitation is now being designed and being applied by the American Locomotive Company to the standard locomotive. They are taking the water from the crown sheet, bringing it out through the side of the boiler, passing it through one of these rotary pumps, using a small engine to drive it, shoving the water along the outside of the boiler in a special chamber called the precipitator, and feeding the water from the injector into the head end of this chamber. It passes through four times the amount of water from the crown sheet, and before it reaches the boiler complete precipitation has taken place, and the precipitation in the form of fine granular is blown off from time to time from the chamber on the side of the boiler.

They have hopes of eliminating most of the boiler cleaning of locomotives.

You can realize that by using small tubes what a great heating area you can get in a small space; in fact, the combustion chamber is the larger in all cases. The combustion chamber is larger than the space utilized for heating surface. The tubes being small, the water section is a very small cross section, and readily heats and generates into steam.

Fast velocity through the tube, having no dead spots, is one thing we have in mind, within the firing zone there shall be no dead spots; every portion shall be swept by the circulation. By doing that we are meeting another condition, and that is rust and electrolysis within the generator. We are forcing into the system, pumping it in,

oil, it must not flash under a 600 degree Fahrenheit and have a paraffin base; we use the paraffin base and that way eliminate the electrolysis, and under the 600 pounds pressure temperature of 486, viscosity is so thin it cannot adhere to any part of the metal and is swept out either as gas or is blown off.

But inside these tubes, open them any place, and you will find all the drawing marks of the tool are there; there will be absolutely nothing on the inside of those tubes. That way we eliminate, first, the scale, then we eliminate the electrolysis, and the eating out of the coils by distilled water.

This system is readily available for condensation systems, and where we are using condensers. There, again, you have the trouble under the present type of boiler with the engine oils entering the boilers, not being all trapped by the traps. We have no fear of traps going bad here, because they are not necessary. We do not worry about how much oil goes back to the system, as it has absolutely no effect as far as the generator is concerned.

Professor Emmet of the General Electric Company, in looking over the system, said there would be one thing he'd want to look up on oil action, and that would be whether or not the oil, some of it, would become carbon through heat and go out through the throttle to the fins of your turbines. He said if there was any great part of the oil that went into carbon and should go out through the throttle it would do the turbine injury. That is a point I have not gone into and do not intend to. I will leave that to some one else.

By this system we can meet several problems that are at the present time interesting the engineers in many countries. The American Locomotive Company have had their experts out here several times, and they told me they have had men travelling in Germany and all over Europe during the last two years looking up various high pressure steam systems with the possibility of utilizing some of those systems for locomotive purposes. The present locomotive, of course, is designed to pull a certain load, but in designing that locomotive it is well known they design the boiler first. First we must have a boiler that will handle the load and build the engine of the best possible design so they can attach that boiler. The ideal way would be to build the engines and then apply a steam generator of such size as would handle the engines. It is the reverse now, and they have reached a limit of area, sky line and wheel base with their present type of steam locomotive. They must now get more steam within the same sky line and same wheel base if they expect to go into more powerful locomotives.

The way of meeting that is high pressure steam, electric driven generators, and electric trucks. It is almost impossible to conceive of a locomotive that you can add more steam to than the present type has, and still get traction using pistons and connecting rods direct to the trucks. There would be about only one way available so far that we can conceive of; that would be to use a geared engine, running the engine at a much higher speed than the axles, and that would give you a much greater starting or pinch on the rail to get started.

The electric drive makes possible the shunting of the motors and starting load with a tremendous leverage, and going back to the original position and traveling at high speed. The electric locomotive itself gives much faster schedules than steam because of its initial starting torque, and that is very desirable for operation on the main line, and by using a high pressure steam system such as this or some other may be developed, and using a high speed circulation, it is possible to build a combustion chamber completely surrounded by water, the water coursing at high velocities around it, and we can then successfully use powdered coal.

There is no type of locomotive boiler today that can operate successfully under powdered coal if it is forced. The boiler tubes and all are too close to the fire. They must have some distance. Under this system, however, Mr. Renney, of the American Locomotive Company, claims we can have a water lined combustion chamber, which soon after commencement of operation would line itself with slag. After that the excess slag would be carried off. And that, by the way, is a problem, just what would be done with that slag. It could not be dropped on the ties, because it would burn out the road, and it could hardly be dropped along the right of way here and there, but it should be, and we believe can be, cast and dropped off at certain designated places and relieved similar to taking on water. We do not consider that as a major problem that cannot be surmounted. The high pressure steam locomotive—some of the red pencil sketches we made of it, and the debates we have had on it resolves itself into a machine of similar construction to this, pilot wheels, of course, on each end. The driving trucks would be gear cranks driven by a motor pivot at this point. That is a pivoted truck. There is a body and another truck of the same specifications at this end, with a drop in the center. This drop would be a little wider than I have shown it here, and there would be the high pressure generator; the other end would be the fuel and water end, and in the center it would be the cab carrying the operator and the dynamos and the turbines or reciprocating engines.

It might be reciprocating engines for this reason: It is almost impossible, in fact, we have no facilities for handling such a large volume of steam as the American Locomotive Company would require, and condense that steam. We might be able to condense 20 per cent of it, and would, perhaps, do that. The condensation, however, not being complete, would cause back pressure, which would not give the turbine the best operation. The reciprocating engine will act against a slight back pressure much more readily than the turbine. This type of locomotive would run in both directions and would generate steam from the start from a flash in not over 20 minutes to bring that locomotive up to full steaming pressure and operation from a cold job.

In these heating elements we do not have tubes that are straight; they may be wound at many turns. Rapid heating does not mean anything as far as expansion is concerned. We have a very small chance of leaking. The hydrostatic pressures we put on all the experimental work is 3,000 pounds. The only reason we don't go higher is our pumps don't go any higher, but tubes and containers will stand from 6,000 to 7,000 pounds pressure. We have here a locomotive of no danger from explosion, but here are the advantages of the combination locomotive which is now being searched out. This locomotive could travel on the third rail or on the overhead electric system; for instance, it could leave New York City with nothing but hot water in the accumulators, and when it got out into Harlem,

cut in the powdered coal fire, it would have no banked fire, no gasses in the New York station, the damper would be on the flue, and striking Harlem the fire would be thrown on, and leaving the electrification it would travel under its own power. Coming into Cleveland, we have the electrified system reaching out to some 10 or 16 miles in order to get terminal changing space. Coming into that section, it would cut out the powdered coal fire, travel in on the overhead trolley system to the station, and would leave on that system, and getting back into the open air would cut back into powdered coal and travel on to Chicago, cutting out the fire when they struck the electrification there. These are very probably facts.

On a steamship we would have, if possible, a tremendous energy available on a few moments' notice without being fired up and ready hours ahead of time. For instance, a ship wants to sail on schedule, and it may have some delay; still, the fires must be under way and everything steamed up a great many hours before the ship leaves. Under this system it would be possible to have a full head of steam and in five to ten minutes' time have the complete power of the ship available by cutting in the fires. As I say, you can cut in a fire wide open without fear of distortion or expansion to your heating surface.

We would have a central set of containers, tubular, manifolds leading off at the bottom. We would have manifolds leading over above the water level, the steam take-off is at the top, to your throttle line. We would have in between these two manifolds a number of firing units arranged in the most suitable position to meet the contours, and the conditions on the ship. In each one of these furnaces we'd have the heating sections. All that would be necessary to throw one of those systems in would be to turn on the fire; immediately it would start on expansion of this pressure in the coil and would become greater than in the accumulators, and the circulation would start. We could keep these accumulators hot with one or two fires, and keep the dynamos and the auxiliaries of the ship going. We could even move out of the berth on the reserve steam in these accumulators and cut in the other fires as we go. We could cut in three or four fires and move down the New York Harbor out toward the open sea. As soon as the ship reached the position where she could travel at full speed ahead, four or five minutes before that point is reached, they'd ring on the bridge for all fires, and when they were ready for speed she'd have a full head of steam.

That becomes a very interesting thing from a naval standpoint. A ship traveling in time of war, trying to conserve her fuel, could use this. Now that we are shooting over the horizon, shooting so far we do not see the object we are shooting at, but need planes to direct our gun-fire, it is necessary that we have all boilers lit. Under this system, when the enemy was sighted, it would be possible to flash all fires and get under full head of steam in a minimum of time without necessity of burning up a lot of unnecessary fuel during the hours and hours the ship would be traveling merely as a scout, and not at high speed, and not in the danger zone.

Another subject, which is far more interesting to me, personally, is the automotive field. We are using a tremendous volume of distilled fuel in this country. As an illustration, the automobiles of this country, some 15,000,000, suppose each car was burning one gallon of fuel a day; we will allow each car that much. It is a well-known fact, if we distilled crude oil for kerosene instead of gasoline, we'd receive three gallons of kerosene in place of one gallon of gasoline. If we burned one gallon of fuel per automobile each day, this would be the consumption—a 6-inch pipe line filled with gasoline from New York to Denver. That would be the consumption in this country in a single day, and if you were filling the gasoline tanks of the automobiles in the United States burning one gallon of gas a day, you'd have the gasoline coming out of this tube at the rate of 100 miles an hour for 24 hours a day. I am merely giving you that sketch to try to visualize the tremendous consumption of fuel of the American automobile. We are utilizing this fuel oil at a tremendous rate. Sooner or later we must face the fact that we cannot use gasoline in such proportions. Consumption is much greater than the illustration I have given you.

I believe we must come to lower grade fuels. I believe in many cases we must eliminate oil fuels entirely. I think the tractor in inter-city hauling, will become one of the big productions in this country in the next few years, for several reasons: One is fuel. We can operate on a very low grade oil fuel if we use a steam-driven tractor. We can also save the destruction of the roads over 85 per cent against the five-ton trucks, and I am going to give you an illustration of what could be accomplished with steam in the way of traffic.

I spent the years of 1912 and 1913 on the desert at the mines with traction engines and motor trucks. I was out for two different companies, the White and the Packard, and in some places we could use trucks, and some places we couldn't. There were mountains drifted over with thousands of feet of sand, thousands of feet deep, and in some places we had to plank the roads and haul cinders and pile on oil. There would be mountains of sand on one end of the valleys one year, and mountains of sand on the other end of the valleys the year after, sand so fine it would just run through your fingers. I have seen the sand blowing at times to the extent that we couldn't see the radiator out in front. During such sand storms we had to have canvas to cover ourselves up to keep our skin from being ground from our faces. All the bearings had to be made special and capped with grease cups and we had to keep the grease oozing out of the bearings to keep the sand from going in. But those years with the motor trucks, engines, and tractors and trailers convinced me of the great possibilities of tractors. When we find the motor truck today, a five-ton chassis carrying a five-ton load, a total of 20,000 pounds, 85 per cent of it on the rear wheels, we find that machine on the road is exerting a pressure of 180 pounds to the square inch. That is almost boiler bursting pressure, and that is what is causing considerable destruction of the highway.

This is the motor truck (drawing), and about 85 per cent of the load is carried on these rear wheels. The rear wheels must necessarily be quite small in order to keep the load near the road. That truck has a 36-inch wheel normally with a hard tire. It is traveling as fast as the speed laws will permit, and a little bit faster, and if you are driving a car and meet one of those trucks, your heart is in your mouth if the truck happens to be traveling at 15, and in some cases as high as 30 miles an hour.

If the weight on that wheel is 85 per cent of the load, and the contact of the wheel is only four inches on the road, and the wheel has a road surface of 12 inches wide, and you have two wheels, the weight on the road with 12-inch wide wheel, two wheels, is 175 pounds to the square inch. That is just load. Now, if you take that truck running at 20 miles an hour, and that wheel leaving the ground, as it does on the road, as in many cases, because of irregularities of the road striking it, you can get some idea of the tremendous pounding effect on the road. You will find why these brick roads get wavy in one season. The more pronounced the wave, the harder the blow.

The road commissioners in this country are very much interested in the possibilities of reducing the destruction on the road to the extent that they have weighing devices, portable ones, and trucks may be stopped any place on the road and the rear axle weighed to find out whether or not it is overloaded. That is costly to the people that own the truck, the user of the truck, it is costly to the roads, it is costly in taxes, and if we could interest the people who are interested in traffic in reducing the speed, we could reduce the road destruction perhaps 85 per cent.

Here is a possibility. Reduce the speed by law, and haul, instead of a five-ton load, say four loads of five tons at 10 miles an hour maximum speed. Trailers would be equipped with air brakes. It is just as feasible as to equip a train with air brakes, and just as necessary. With the air brake system, the operator would have full control, and we'd be reducing the speed to 10 miles an hour, which would give us a train on the road, which would not be weaving because of great speed; it would be following the tractor, and it could pass down a hill without danger, as all wheels would be brake wheels.

At the head of this train we would have a steam tractor, which would not weigh over seven tons, would not have to weigh over that to give traction. The wheels would have a base of 17 inches with 42 inches in diameter, and with a 14,000 pound job or seven ton tractor we would have a road weight of only 55 pounds against 180 pounds. The speed of the device would be 10 miles an hour, one-half the speed of the other job.

On a truck carrying heavy freight and transporting same we now find two men, the helper and the driver. Taking the same crew here we would operate just twice the ton mileage, operate a 20-ton load with great safety, one-third the weight on the road, and we would double the ton mileage with the same crew.

This tractor would be burning fuel oil. It would steam up in a few minutes' time, not more than 10 minutes, and the wearing parts would take eight years to turn over as many times as the gas job turns over in two years. That is saving on wear and tear. The upkeep would be far less. There is no reason why a steam tractor on the public highway could not be as efficient and long lived as the locomotive on the railroad. We now wipe out the truck in five years' time, and we charge it off the books. There is no reason why we could not keep a steam tractor on the job 20 years.

I know in my youth, on the farms, our old steam threshing engines were an institution in the country before we fellows were born, and I passed on out of that district into the industrial sections of the East, and the same engines that were running as far back as I could remember were the same engines doing the threshing when I left. Then the gas tractor came, and they were going to run out the steam engine. So we bought the gas tractors, used them one season, put them under the willow hedge, and got out the steam engine, burning coal, pulling the machines, and giving positive results on the day we were going to do the threshing, and all through the season.

This tractor would have 216 square inches of traction surface; the truck would be carrying a five-ton load at 20 miles an hour, the steam tractor would be carrying a 20-ton load at 10 miles an hour, and would have the possibility of delivering and segregating the loads and distributing them; you couldn't do that with the truck.

The automobile pleasure car will come last if we have a steam automobile. There has been a great deal of talk about it, and I have built four or five cars. I spent $25,000 on the last car. It was a very nice running car, but I didn't have it to the point where I would want to turn it over to the public or production. I think the steam car will come with education. It certainly is a much more beautiful thing to handle than the gas car will ever be. The steam car is a positive power. To be hit on a railroad track with a steam car would be a disgrace, because you have instant action. You can get away from anything you can see coming if your steam is 500 pounds; you can just tickle it with your little finger. You will have no spitting carburetor, no missing, no stall.

In a steam car of 20-horse power, you have this remarkable fact. My last car, of which I have pictures here, weighed about the same as the Cadillac open touring car. That car would travel 16 miles on a gallon of kerosene. That sounds rather strange; the Cadillac car was traveling around 10. It sounds as though I were saying the steam engine is as efficient on a pound of fuel as the gas engine. I am not saying that. I am saying this: Outside of the laboratory the automobile interests say, how far can we go on our pocketbook, how many telegraph poles can we pass? That is what is interesting us, not what we are doing on the block. If I took the power plant of my steam car into the laboratory, against, we will say, the Cadillac engine— I am merely selecting that car as one of the standard automobiles—immediately a howl would go up that I wouldn't be playing fair. They'd say, "You have a very much smaller plant, our is a 57-horse power plant, and you have a 20-horse power plant."

I'd say, "That is true, but this is the plant I used on the road, and I will travel as fast as you do, and just as far, and I am running 16 miles on a gallon of kerosene costing me, normalls, half as much, and you are running ten."

Here is the fact—that 57-horse power engine in that tractor or truck is only being used a small portion at a time under full power. You are operating a larger gas engine than you need about 90 per cent of the time, so you will have a big engine and lots of power when you need it to get off of that railroad track, to get through the traffic, to get out of the way. You are using a big engine only a small part of the time. You are running a big engine 90 per cent of the time way below its load. Very expensive fuel consumption. While, with the steam job, you have a 20-horse power output continuously, but you charge accumulators with temperature, and when you want the power you throw

your throttle open, and you have more power than your wheels can hang onto, because you can deliver from those pistons, by throwing in that excess pressure around 120-horse power if your wheels will hang on, with your 20-horse power job.

The steam car has always been noted for tremendous acceleration. That does not mean it can keep up that speed, but we can use it while we want it, can jump through the traffic, can be master of the road, whenever you want that power you have got it. You have it for several miles, enough to discourage the fellow following you with a gasoline engine if you have the nerve to open up.

I think the steam car will come; ahead of it will come the industrial tractor, and then the steam bus, or possibly the bus may come first. It is very essential that we get steam into these passenger buses. They have to lay behind the street car; the street car has a tremendous power reserve for torque in starting, and it makes a tremendous start. The bus cannot meet the street car speed and get away with it. The result is, while it is in the city, the bus takes great chances on the passengers' lives and the people on the road if it tries to pass a car.

If it had steam power, a 30-horse power steam engine it would give that bus in an emergency around 200-horse power for reserve to meet the torque necessary, which you can't possibly get from gas.

The Chicago Yellow Coach Company are entering the bus field in a very heavy way. They intend to take the bus field if they can. I have been down there giving them my ideas of steam at their request. They even offered to furnish me a chassis to equip, and they are now building busses which will be shown this winter at the shows of 135-horse power gasoline engines.

That is expensive. The people that buy them are buying them to make money, not to burn fuel, and I think the steam bus is certainly the coming bus. You get in a bus and go from here down to Akron and you get an awful gear humming, and it keeps you on edge all the way down there. That would be eliminated in a steam-driven bus; there is no sound to your mechanism, no vibration, and your parts on that bus would turn over in eight years the same number of revolutions they turn over in the gas bus in two years. That means you cut down your mechanical upkeep.

I am quite sure the automotive field will go to steam, first in the heavy units, and then a portion of the pleasure cars, because we will be driven there, if for no other reason, by a shortage of fuel. But the second factor will come into it when we start to use them in any quantity at all, and that will be the wonderful control of the car in the hands of the most amateur operator, and they will be extremely surprised at the simplicity of it. There will be several hundred less parts, and the great mass of automatics, known heretofore in steam cars, will have been wiped out, because of the automatic control that is possible today is exceedingly simple, and there are not as many moving parts in the whole car as you'd find in the average magneto of the gas car. The control on this system is very simple. We do not watch water glasses; we have no water glass. We do not watch valves or test for water level. We simply forget the water end of it entirely. If the water tank is dry, that means nothing except she shuts down; she quits; you can't burn it up. The water level is controlled by expansion and contraction, due to the various positions of the water level. It is very positive. That same element utilized on the fuel end will shut off the fire entirely if the water goes below a certain point. If those should all fail because of the high speed circulation we use, and with great success, an old time safety soft plug; with all the water of the system pouring on that plug it is not possible for any oil or sediment to stay on top of the plug; it is clean and bright, just as clean as when you put it in. Let the water go below, and she blows out. That is a positive safety feature none of us doubt.

The high pressure system, in my opinion, is becoming a merry contest between combustion engines and the high pressure steam system. I will be glad to answer any questions.

DISCUSSION

R. E. Brakeman*: I don't know what to ask. I'd say this, as far as my work is concerned, if it would take the place of the big motor we have down in Blooming mill, I would be very much interested.

I think Mr. Barlow has given us a very fine talk. It is a subject which I know very little about, and could not possibly discuss in a meeting of this kind, because of its newness, and I am rather doubtful of the method of application. Apparently the scheme has been on the map long enough to have proven itself to some people, and it is well worth while, or the money that has been spent would not have been spent, and the money in sight, which will be spent, wouldn't be.

I have always thought there was a great place for the steam engine in the tractor game. I don't know why several who have tried it have dropped out, perhaps because it was so cumbersome. I know a man who, after having seen one of these steam automobiles, went back to his plant and called the pipe foreman and said, "Gus, you don't want a chauffeur with that thing, you want a pipe-fitter."

F. H. Covers: Mr. Chairman and Members of the Association: I just want to express my profound appreciation of this opportunity to hear Mr. Barlow's most excellent talk on this device that has so many possibilities.

There are several questions that came to my mind. Outstanding was one regarding the efficiency of the device, not including the turbines; just the efficiency of the steam-making device.

And it is not quite clear to me how you are going to protect the heating element if the automatics fail and there being no water, a red hot tube under pressure, results. How are you going to protect it? How are you going to prevent disaster?

I suppose this pump, that apparently feeds the water is provided with valves.

Those are the outstanding questions that came to my mind during the interesting talk.

R. E. Brakeman: It would be interesting to know whether or not an application of this somewhere

*Chief Engr., Otis Steel Co., Cleveland, Ohio.

in the United States—if there is an application—and if a person stopping in the locality might look at it.

Whether it is successful, whether it is far better than the present steam locomotive, or whether it is far behind it?

M. M. Nesbit I have enjoyed this talk very much, and was particularly interested in what the speaker was telling us about the application in regard to locomotives. I'd like to ask what voltages they find most successful for operation of locomotives, particularly where it might be desired to operate on a trolley with the third rail system. I'd also like to have him tell me the relative size and weight of one of these locomotives, such as he drew on the board, the electric traction locomotives the New York Central are using out of New York.

L. P. Barlow: In regard to the first question, efficiency, the efficiency of this system I would not say would be any higher or even as high as the later development of central plants where you have unlimited room and height. It is a system developed for very cramped positions, and where the efficiency is bound to be much higher than the present type of boilers, for instance, the locomotive boiler. We are trying very hard to get water tube locomotive boilers.

There are in this country at the present time, two or three locomotives under experimental operation, but they are limited to height, and we must have height in order to get the weight of the water column, and they have not proven very successful. This system does not depend on height for circulation. The hot tubes. If you have water traveling at high velocity, and a great volume of it against fusible plug, there is very little chance of the tubes becoming hot, because the plug certainly will go before the tubes can become hot, and in case of a low water level or an automatic failing the plug would go. That would be the final safety. That is not possible where you have a sluggish circulation, but where you have a given volume of water, and continuous, you can hold a plug against high pressures. I have held soft plugs against 1,000 pounds.

The submarine question has been answered. There would be no fire below the water surface. A locomotive operating in France has no fire at any time. It is running some four or five miles charged with steam at each end, and that is the theory referred to in regard to submarines. They would cut out the fire on submerging and they must have a capacity. They must have capacity of storing steam or water under temperature sufficient to operate that boat one hour under full speed under the surface. Their range of power reduced to three knots an hour would give the boat headway, steering for 34 hours. It is not difficult to maintain the temperature.

F. H. Cover: In other words, your storage system is just a regenerator?

L. P. Barlow: The circulating pump is operated directly in proportion to expansion to its relation of area between the two ends. If it is a three to one head, expansion takes place of two to one or three to one before the pressure rises sufficient to move the piston. Any increase in that expansion will force the piston and then as the exhaust over to the accumulators takes place, you get the drop of pressure and release of it back to the accumulators, but there is an expansion in the coil. It is not solid water. It is solid water when it goes into the coil, but going past the steam cylinder it must expand more than 3 to 1. After it leaves the piston we get the drop, for instance, we started out with 20 pounds of pressure on the coil and zero in the accumulators. As soon as the pressure arose to five pounds in the accumulators, we'd have 25 pounds on the coil. We find there is a difference there, the heat greater resistance, and the greater pressure difference between the two sides, but they range generally between 15 and 25 pounds difference between the two pressures. As your pressure goes up on your gauge, you have accordingly higher pressure going up on the coil side. If your accumulators drop pressure, it speeds up circulation just due to the drop of pressure, and not just due to increased temperature.

Range of pressure—a critical range— would be a very high temperature. I have never gone up to that critical point. That would be around 3,200 pounds pressure, I believe. I couldn't answer that right now, because there again we depend on mechanical action, due to expansion, which is water, of course, solid water. That is something I haven't thought of, but down around the 600-pound mark to 900, where I worked, there would be, of course, no question. I found the 600 pounds to be the most acceptable for my work, because of the temperature. If you go much beyond 600 pounds pressure your temperature becomes so high when you add superheat, the durability of your metal on the valves is affected.

It is a very common occurrence at 600 pounds pressure, when you have a pipe leading away from your superheater you can see it red hot in daylight with only steam to heat it.

Where can you see it? We have built one of these devices at the Brown Hoist Company. It is the largest unit I have built; it is for a locomotive crane, and we have had it in operation; it is a piston driven pump. Rotary. I am now doing some development work on that. As a pump, it is very efficient. The steam head of the thing still needs some development work on it, but the speed of it, and the answer to the different temperatures is very responsive.

If I am at the Brown Hoist I will be glad to show you. The trouble is, I am here, there, and the other place, and although I have shown this device to a great many people, there is nothing secret about it.

As I say, we are having quite a strenuous patent scrap. I think my greatest difficulty with this—it is a fact, that these things do leak out of the Patent office. This patent was granted, allowed, and then suddenly there seemed to be great pressure exerted against it, although it was a special patent demanding immediate action, no delays. After it was granted there was suddenly resistance thrown against it, and the patent was withdrawn, and they were citing some 12 different patents which didn't even touch the subject. I took a trip to Washington to answer it, and those were immediately wiped out, but it seemed to me they were after a delay. One thing led to another until the second allowance was made, and then that was withdrawn. The last thing that happened which started a fight that is going to be a trouble-maker, was an old, obsolete number in the Patent office (under the laws of the country a patent number cannot remain in the Patent office over two years, that is the Supreme Court decision, without having anything allowed on it and

still be a live number.) A numer considerably older than that was taken and stripped of all data, and the first thing I knew I found a prior claim against me, but all of the matter attached to the claim was identical, every comma and every period, every word exactly as we had written it. When I confronted the Patent Commissioner with that he denied it. I got out the records and proved it. He said it was necessary in determining this contest to copy one side or the other. I don't think the American people intend that at all. That is a situation I don't know where the opposition is coming from, but we are having considerable of it, and that is a little bit of what we are running up against. It is not new, however. I have known it to happen before.

In regard to the turbine locomotive of Germany. I only know what I have been told by the American Locomotive people, but the principal drawback of the turbine locomotive is condensation. There must be some vacuum. With the locomotive the area is so limited they can't get efficient condensers for the system. I don't believe we will have many big successful turbine-driven locomotives. I think it will be the electric truck. The voltages of the locomotive. I am not an electrical expert, and I will not try to answer that.

The size of the locomotive can be maintained within the limities of the present electric locomotive, and the weight would have to be sufficient to carry a ballast in order to bring the weight up to traction.

Accident Prevention

By WALTER GREENWOOD*

IN discussing our subject, the term accident is applied alike to concurrences which result in injury to persons and in damage to equipment.

The very nature of our subject makes discussion of it a serious matter. Since accidents are the cause of suffering and sorrow as well as financial loss, it seems out of place to treat the subject with any degree of levity. The ability to interweave descriptive narratives with humorous tales, or to give some phase of it a humorous tinge, is characteristic of some writers and orators, but how could humorous narrative be injected into subjects that are painful or sad like funeral sermons or sufferings of humanity? Mark Twain reached the sublime in his description of the Sphynx and the Pyramids of Egypt, and in the same description he arouses mirth, by narrating alleged experiences. Dickens in his Tale of Two Cities pictures the work of grave robbers in a way that arouses both disgust and mirth, by the description given in each line of the narrative. It might seem that injecting humor in the discussion of accident prevention is in line with treating the subject as a matter that affects efficiency or as effects cost of production and entails financial loss to the community at large.

Saying something to electrical engineers concerning safety as relates to construction, installation and operation of electrical equipment, makes me feel that I might be looked on as one who is presumptious. About all that I can say is gathered from a little observation, and the experiences related by practical operators as to conditions that are not entirely manifest to designers, manufacturers, and purchasers of equipment. One of the qualifications that makes a safety engineer efficient is his willingness to insistently demand correction of manifest faults.

One of our complaints is, that the matter of cost of installation, together with the alleged complication that affects maintainance, is used in the arguments against our demands, because it is considered that equipment, no matter how primitive it may be, can be operated without accidents if only caution is exercised or, in other words, if everybody will do exactly what they should do. No account is taken of the exigencies that compel the employment, in a large majority of cases, of men who have not had the advantage of higher education that includes technical training, the substitute for which is experience, and this cannot be quickly acquired. However, we are constrained to say that eternal hammering will bring everyone to realize the value of providing for safety in first installations and that this is as important as education.

The term accident is so commonly and almost exclusively applied to injuries suffered by individuals we have almost forgotten that it also applies to equipment damaged by some occurrence not intended. The measure of this latter class of accidents is taken in dollars. Laying aside sentiment, there is no comprehensive way of measuring results of accidents to persons other than by entering the cost in the ledger as items of expense that affect cost of production. Measuring by the dollar standard may seem like a cold blooded view to take of a matter that is often the cause of great grief, and usually results in greater financial loss to the unfortunate victims or their dependents, than to the employer who entered an expense charge in the ledger. There was a time when the only charge against expense for accidents was the items that covered those that resulted in damage to equipment, but today the expense for both classes must appear on the ledger. This imposes no hardship on industries, as the cost is distributed over the community the same as though it was cared for by other methods. There is no denying that employers deplore destruction of human life and maiming of limb, nor can we say they deplore it any more today than they did in the days when the expense account was not compelled to bear the burden of such charges as have been fixed by state to reimburse the injured or the dependents of those that are killed, but we cannot claim that sympathy has a measurable value. Anyhow, saddling the burden of indemnity on the cost of production, where it rightfully belongs, has been largely instrumental in arousing employers of labor to action, and in proving that rightly directed effort

*Safety Engineer, Ohio Works, Carnegie Steel Company, Youngstown, Ohio.

will result in avoiding damage to equipment and injury to persons. At one time it was the opinion of many, perhaps it is yet, that safe-guarding equipment and providing means for operation believed to be safe, would have no perceptible effect in lowering accident hazard, but results go to show the error of such an assumption. Credit is given to both safeguarding and educational training. How much, expressed in numbers, should be credited to each is only a matter of conjecture. While now we have better methods for determining the relation of these numbers to each other it still is to a considerable extent a matter of arbitrary classification. However, there still remains much to be done in the way of safeguarding, providing safe equipment and means or methods for operating that will lower accident hazard.

Fundamental principles that relate to efficiency and safe operation of electrical equipment are fairly well understood. The full application of them is not so much neglected because of lack of knowledge as because of lack of capital in some cases, and fear to invest it in others. Nothing has yet been done toward making electrical equipment more efficient that did not result in making it more safe, and nothing has been done to make it more safe that did not result in higher producing efficiency. It is to be deplored that the generating capacity for present and future requirements cannot always be properly estimated, as the operating of it up to the very outside limit of its capacity, which generally means in excess of rated capacity and up to its excess limits, is always attended with some hazard. While control equipment can be provided that is intended to prevent operating beyond predetermined limits such apparatus is liable to failure or to be out of commission for some cause, then uncontrolled excess demand on one part places excessive duty on other parts and this usually results in accidents and delays that mean financial loss.

We may contend that we cannot lose that which we never possessed; that as our profits are based on producing up to our rated capacity there is no excuse for trying to produce above it, then if we keep within the rated limits there will be no accidents from trying to exceed our rated capacity, and there will be no loss if we fail to produce in excess of this capacity when it is possible. Instability of business conditions compel close competition at times, and success is largely dependent on producing up to the highest possible limit when we can, as the excess of rated production at some periods must apply on the deficiencies of other periods. Loss of production caused by accidental delays cause financial loss like that which occurs through mishaps that involve an outlay of money.

Running main conductors in subways and underground has much to do with accident prevention. While such installations are expensive, our observation has been that the saving they could effect by avoidance of injury to equipment from various causes, would amount to more in a given period of time than the difference in cost between underground and overhead installations. Not long ago, while making some kind of inspection on top of a 2500 volt generating outfit, a yard crane in a remotely located section of the works, grounded a circuit with its boom. Several coils of the generator went up with a flash and explosive sound that made the locality look unhealthy. While not conscious of being excited I was extremely anxious to get away, and finally succeeded by a route that took me close to the generator, while I was uncertain about what was yet to be pulled off. After getting down on the floor I said, in the language used by the presiding officer at a meeting of citizens in a Pennsylvania town, assembled for discussion of civic betterment, after a motion had been disposed of, "vot der hell next!" The loss from this mishap, when every factor involved is considered, conservatively estimated would exceed $4,000.00. It is but one of the many accidents that can be cited within the experience of operating any industry of considerable size, where electric power delivered through overhead lines is employed. It is owing to the fact my heart was in good condition that the expense for a fatality was not added to the cost.

Effort along the line of standardization has done much toward decreasing accident hazard, yet there is much more that can be done. Some time ago, when the A. of I. & S. E. E. revised the overhead traveling crane general specifications which they previously had approved and printed in their proceedings, an effort was made to have its standardization committee approve of equipping hot metal cranes with double main hoist equipment for handling ladles, but further than to suggest the method for making such installations, it was not agreed to include it in the requirements. To safety engineers who consider results from the cost side, as well as the sentimental, it looks as though their failure to do this showed lack of courage. The patents on interlocking features for assuring synchronous operation of the two hoists do not make the installing of them a monopoly. There now is more than one good method for doing the trick and probably any crane builder can devise others that will perform the office satisfactorily. The actual direct charge that has been added to the cost of production through accidents that resulted from failure of hoist equipment handling molten material, and which might have been avoided had properly constructed double main hoists been employed, would have, had such a sum been so applied, resulted in a saving of more than the difference in cost between them and such as are now employed. Furthermore, it is not likely that these charges against the cost of production are going to cease before all hot metal hoists are so constructed.

The crane specifications do not include all the requirements necessary for making sheave blocks as safe as they could be made, yet as they generally are made, they constitute a high hazard. They can be so made that the cable cannot get out of the sheave groove and be damaged thereby, and, too, they could be constructed so that it would be impossible for any falling object to get between the sheave and cable, or for anyone to get their hand caught. General specifications governing the construction of sheave blocks, regardless of where they may be used, should be provided.

Lack of its efficiency and failure of control and regulating equipment is responsible for many accidents and delays. Installations may be made that are sufficient for expected requirements, but as demands increase more load is imposed without maintaining the original high margin of safety or con-

trolling efficiency. Control designed for automatic operation and for manual operation can be the cause of accidents if it fails to function; especially is this true of overspeed control and travel limit devices. Control equipment designed for every possible contingency that can be foreseen that will jeopardize life or property, justifies all the expenditure that may be required for installing it. Simple devices of cheap construction for control will take care of some ordinary conditions, but the majority of accidents result where they are not expected to or where provision is not made to take care of extraordinary conditions. Of course, much is dependent on careful inspection, good maintainance and careful operation, but in many cases operators of equipment are subject to orders given by persons in authority who arbitrarily command without knowledge of capacity or sufficient care for what results to it. They cannot understand why electrically operated equipment, like animal power, will not stall before breaking something and they then are too prone to think it is because the department responsible for upkeep has been in some manner negligent. Of course, the adjustment of control to care for starting conditions and overloads within allowable limits for permissible periods of time, is a more or less difficult and vexatious matter for electricians to comply with, but this does not seem to be justification for neglecting to supply effective control within predetermined limits, then if the load to be moved is too great divide it or find another means for handling it. The dread of adding complications by going far in the matter of providing control is, to some extent, a bugaboo with operators of electrical equipment, but they must remember that no great advance for the betterment of conditions that affect industries, has been made without overcoming obstacles that seemed to be insurmountable. We have not intended to deal with specific cases in discussing control, but we will call attention to a case that may seem to be unimportant where a serious hazard exists because of insufficient control, and perhaps it has not been brought to the attention of manufacturers in order to give them a chance to overcome the defect. Mona rail hoists and stationary suspended hoists usually are manipulated by anybody and everybody. The limit stops usually provided will operate satisfactorily when the motor runs in the direction intended for hoisting, but when ignorantly operated in the other direction to make a lift will, if contact is made by the limit, injure the limit and make it inoperative. Perhaps the limit might be constructed so that it will be operative regardless of the direction of motor travel. In case this scheme is not feasible the hoist cable can be and should be so connected to the drum that when the last coil is run off while motor is running in the lowering direction it will automatically become detached. With various other kinds of hoists, in order to avoid accidents, a means should be provided for preventing them from lifting a load with the cable drum traveling in the direction intended for lowering.

There is a noticeable degree of variation in the hazard connected with the different applications of power to driving generators. Hydraulic power should be low in hazard, but its application is not general enough in the iron and steel industry to consider it as a substitute for all other current generating power. Combustion engines using any kind of gas are accompanied with hazard; especially is this true of engines using blast furnace gas from the point where it originates to the exhaust from cylinders of unconsumed products. With this gas there is a hazard in cleaning it, maintaining a constant gasometer pressure, keeping it separated from air, and avoiding leakage in vicinity where operators are employed. Where it is used for generating steam the hazard is much lower than when used in combustion engines as the operation connected with handling it are much more simple. The efficiency of reciprocating engines and turbines as regards cost of upkeep and continuity of service is measurable and comparable, with these considerations in one case balancing those in the other case, preference should be given to the one carrying the least hazard and is the least vexatious to those in charge of operations.

Oil circuit breakers and transformers, through explosions, are accountable for too many accidents that cause serious injury to persons and costly damage to equipment. It is safe to say such accidents would be less frequent and less serious if every known precaution was practiced for their avoidance and every known method was supplied for confining the damage to the apparatus in which explosions occur. Probably there is no fixed limit of time with any operating conditions for water to accumulate, and reduce the dialectric strength of the oil, or for the accumulation of other impurities which have an injurious effect. With these accumulations present, ordinary operation of the apparatus causes heating of the oil and exidation to take place. Through further results, local overheating and breaking down of insulation occurs. These physical changes are followed by chemical changes, particularly generation of gases. Such explosive mixtures as are by chemical changes, particularly generation of gases. Such explosive mixtures as are present may be ignited by arcing or some other accidental means. How to remove the cause is common knowledge, or at least the knowledge can be procured, but in too many cases the dictates of economy, which proves to be false, prevents application of the remedy. Inspection of the oil should be made frequently. Perhaps a better suggestion would be, oil should be changed at stated regular periods and the apparatus thoroughly cleaned, regardless of what inspections show. The feasibility of thorough cleaning may be questioned, but if it is important, where there is a will there is a way.

Some of the suggestions contained in this discussion may seem to be over refinement of safeguarding, but we must consider that the force exerted by this something called electricity is very sudden and destructive. Its movement is even faster than light and sound as was described by the farmer who witnessed the destruction of his chicken coop from a distance. He said the lightning came along and hit it, then the thunder came along and tore it all to pieces. He did not realize the damage was done before he heard or saw the agency. The hazard existing in every case herein mentioned could be mitigated to a great extent by enforcement of standard methods of operating and by installing equipment conforming to standard general requirements for safety. The same is equally applicable to all equipment employed in the iron and steel industry.

RECOVERING ARMATURE SHAFTS WITH ARC WELDING

By T. C. DAWSON*

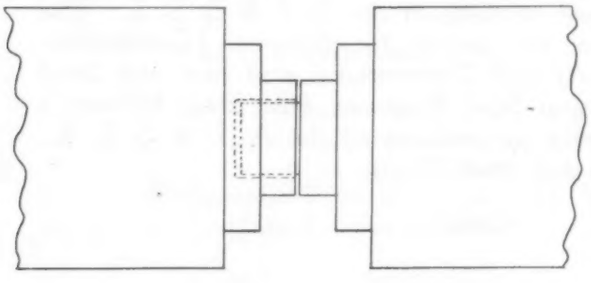
The application of arc welding to the salvaging of worn surfaces on armature shafts, brake hubs and other similar material has proven very economical in recent years.

In many instances, it has been necessary to apply, cut and try methods until the best practice has been developed for particular jobs. With shafts under two (2) inches in diameter, particular care must be exercised to avoid excessive warping due to uneven application of heat. To avoid warping the following procedure is recommended.

(1) Broken Shafts

The shaft should be placed in a lathe and turned down in steps well back from the break, as shown in Figure 1, with an additional piece to replace the broken end similarly stepped down to make a male and female joint, as shown. The portion of the shaft making this joint varies in diameter according to the finished diameter of the shaft. As a rule, it

FIG. 1.



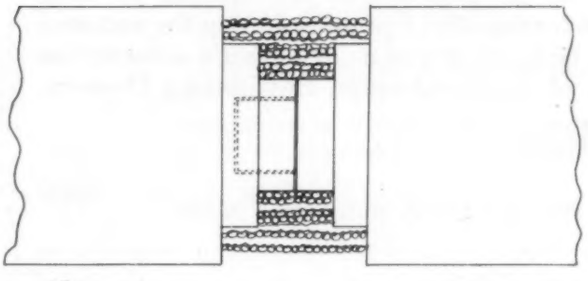


FIG 2.

is one-half (½) to five eights (⅝) inch in diameter for average shafts and should be a tight driving fit.

The first head should follow the diameter of the shaft, as shown in Figure 2. This method gives a fairly even distribution of heat to the shaft and prevents excessive warping, whereas if the first head is run lengthwise of the shaft, warping will occur, especially on small-size shafts.

The next head should then be run lengthwise and the shaft built up in alternate layers, as shown. If possible, the last layer should be run around the shaft, as this provides a better finished surface than a top layer run lengthwise. Welds of this kind have proved entirely satisfactory and no case has occurred where the shaft has broken in the weld or adjacent to it.

(2) Worn Surfaces

Where the surface of a shaft is only slightly worn a thin cut is usually taken on the shaft to provide a clean surface for welding and also to leave sufficient thickness of metal after turning to size so that pealing will not occur. One bead is then applied, or two, if necessary, the beads being again run around the shaft and not lengthwise.

The teeth on brake hubs, which are badly worn, are also welded and machined to size in this manner with satisfactory results, no especial care or preparation is necessary for this type weld, as the large body of metal quickly carries the heat away and no warping occurs in welding work of this kind.

*Bethlehem Steel Co., Bethlehem, Pa.

George W. Quentin, formerly Sales Engineer for the Duquesne Light Company of Pittsburgh, has been appointed Sales Representative for the American Blower Company, with offices in the Oliver Building, Pittsburgh, Pa.

On March 28th the Pittsburgh office of the Crocker Wheeler Company, in charge of J. R. Lewis, moved from the Henry W. Oliver Building, to the Dravo Building, 300 Penn avenue, Pittsburgh, Pa. This office will have a warehouse in which a stock of fro m100 to 150 motors will be carried.

S. M. Conant, formerly in charge of the Baltimore office, has been appointed Assistant Sales Manager and is now located at Ampere, N. J.

The Crocker Wheeler Company, Ampere, N. J., has closed its Baltimore office and has opened an office in Atlanta, Ga., at 101 Marietta Building. This office is in charge of Geo. D. Anderson, Jr.

The Strom Ball Bearing Manufacturing Company of Chicago have just issued a very attractive booklet describing the Super-Strom ball bearing from the viewpoints of design, dimensions, materials, workmanship and load carrying capacities.

Announcement is also made that Arthur W. Wiese has been appointed manager of the Philadelphia office of the Strom Ball Bearing Company, 309 Lincoln Building.

The Thompson Electric Company has just completed the printing of their new Catalog B 25, describing in detail the subject of Lamp Maintenance Equipment. A copy of the booklet may be had by addressing the company at 226 St. Clair avenue, N. E., Cleveland, Ohio.

A new 16 page catalog, B 6, has just been placed in the mails by the Martindale Electric Company of Cleveland, Ohio. The book has to do with Motor Maintenance Equipment with special reference to Commutator Slotting and Grinding Equipment.

Iron and Steel Industry's

Combustion Engineering Division

Associated With
Association of Iron & Steel Electrical Engineers

PURPOSE

The Combustion Engineering Division of the A. I. & S. E. E. is composed of engineers whose problems have to do with the economical uses of Fuel in the processing and production of Iron and Steel.

ACTIVITIES

The activities of the Combustion Engineering Division are confined exclusively to the Iron and Steel Industry. The main object is the improving of all fuel consuming equipment, both primary and auxiliary, i. e., coke ovens, blast furnaces, open hearth furnaces, gas producers, heating furnaces, steam boilers, steam engines and gas engines.

MEMBERSHIP

Every member is entitled to the proceedings and transactions of the Cleveland, Pittsburgh, Birmingham, Philadelphia and Chicago sections of the A. I. & S. E. E. The proceedings of the Fuel Savings Conference, the use of the National Headquarters clearing house for data, attendance at the Annual Conventions, and Iron and Steel Exposition, the Monthly issue of the Iron and Steel Engineer (the Steel Industry's recognized engineering periodical) the Yearly transactions of the A. I. & S. E. E., the privileges of all inspection trips to Iron and Steel Plants.

Date.....

To the Combustion Engineering Division:

Application is hereby made for admission to the Combustion Engineering Division of the A. I. & S. E. E. Upon notification of such admission I promise to pay the entrance fee of $10.00, and dues of $10.00, $5.00 thereof being in payment of a year's subscription to the Iron and Steel Engineer, the official organ of the Combustion Engineering Division.

Name.....

Residence .....St. .....City .....State

State present position.....

Company .....

City .....State .....

Return this application to any one of the following:

W. P. Chandler, Spec. Engr., Carnegie Steel Company, Pittsburgh, Pa.
Walter Flanagan, Steam Engr., Carnegie Steel Co., Youngstown, Ohio.
H. C. Siebert, Comb. Engineer, Bethlehem Steel Co., Bethlehem, Pa.
Strickland Kneass, Jr., Steam Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio.
Mr. G. R. McDermott, Asst. Chief Engr., Illinois Steel Co., So. Chicago, Ill.
Mr. F. G. Cutler, Chief Bureau of Steam Eng., Tennessee Coal Iron and Railroad Co., Ensley, Ala.
Mr. A. G. Witting, Asst. Chief Engr., Illinois Steel Co., Gary, Ind.
E. W. Trexler, Comb. & Steam Engr., Bethlehem Steel Co., Johnstown, Pa.
W. J. Harper, Steam Engr., Donner Steel Co., Buffalo, N. Y.
Mr. C. H. Hunt, Chief Engr., Weirton Steel Co., Weirton, W. Va.
Mr. J. C. Allen, Chief Engr., Carnegie Steel Company, New Castle, Pa.
Mr. A. Steed, Supt. Power Div., American Rolling Mill Co., Middletown, Ohio.